TOPICS IN WATER USE: NORTHWEST MISSOURI

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Table of Contents

List of Figures

List of Tables

1.

Introduction

The Missouri Water Resources Law (RSMo 640.400) authorizes the state water resources plan to address water needs for the following uses: drinking, agriculture, industry, recreation and environmental protection. Addressing water "needs" requires us to establish why these needs exist in the first place. In some cases, an existing water need is tied to one or more unresolved water problems. For example, communities "need" clean water. To meet this need, communities may have to address problems with water supply infrastructure, adequate supply, and source water quality. This report explores current issues facing the water resources of the northwestern Missouri region. It also includes a brief section addressing water use opportunities or success stories. By taking note of successes (and opportunities for success) we recognize approaches that work, and can use them as stepping stones to problem resolution.

As noted in the legislation, there are many aspects of water use problems. Missouri water law is concerned with protecting both private individual water rights and the public health and welfare. In addition to social and economic needs, there are the environmental needs of the forests, fish and wildlife of Missouri. Also, to complicate matters further, there are the facets of quantity (supply) and quality of the water resources and the political jurisdictions that administer water supplies under Missouri statutes. It is within this matrix of considerations that this report approaches these regional water use problems and opportunities as well as the broader topic of state water planning.

To ensure equal consideration for all uses, emphasis is placed on identifying water use problems in each topical area identified in the Missouri Water Resources Law. Similar topics are sometimes addressed in more than one category, reflecting the different viewpoints of people who raised these topics as water use problems.

Although considered individually in this report, water use problems are not truly independent of each other. When reading water use problems identified in northwestern Missouri, it will quickly become apparent that many of them are, in fact, very closely related. In addition, because of the diverse perspectives the various contributors bring to this effort, what from one standpoint may appear to be a "serious problem" may not seem so from another. For these reasons, the following problems underscore the importance of working cooperatively in addressing the water use problems facing northwestern Missouri.

Water resource professionals commonly subdivide the state into physiographic units such as watersheds or aquifers. While this approach is important for resource-based discussions, it may not sufficiently address water use problems or solutions. In this series of reports, the subject is addressed using the broad geographic similarities of the six field service areas of the Missouri Department of Natural Resources field offices (figure 1). Each of these regions has distinctive physiographic features and socioeconomic characteristics, and therefore were chosen for the ease of referencing water use problems. This approach allows us to recognize Missouri's diversity, and lends itself well to this phase of the Missouri State Water Plan.

The area served by the department's Kansas City Regional Office is the focus of this report. Staff from this office and other state agen-

cies dealing with water resources were the primary sources of input for this effort. This enables the Missouri State Water Plan staff to draw upon the insight and experience of field staff who, by virtue of their work, deal with many water use issues facing northwestern Missouri on a daily basis.

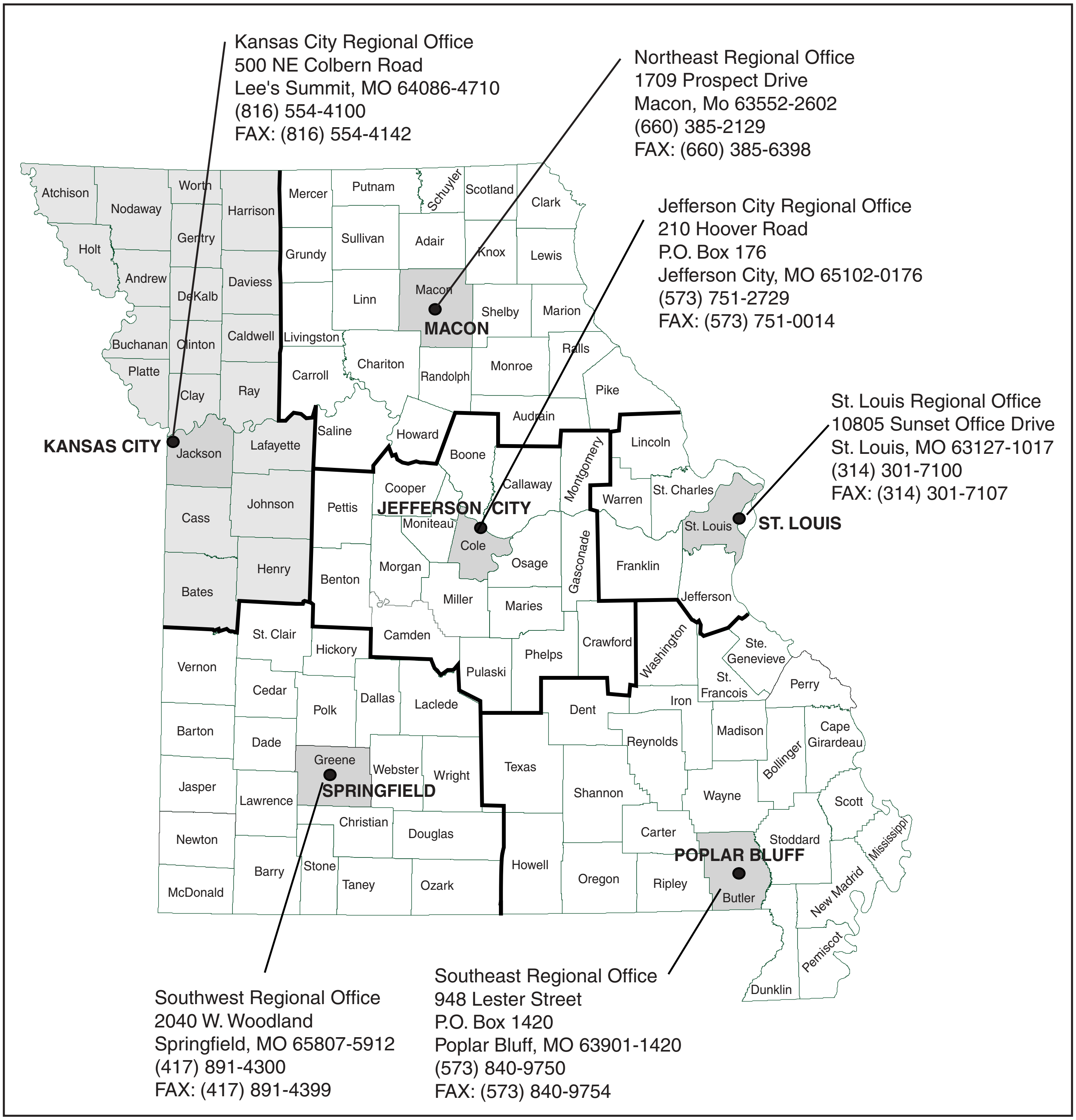

Figure 1. Missouri Department of Natural Resources' regional office service areas.

The Watershed Based Approach

Watersheds are defined as the areas of land that drain surface water runoff into a central watercourse. The watershed usually bears the name of its stream, such as the Blackwater River Watershed. In the 1990s, federal and state environmental planners began to put a greater emphasis on consideration of water resources and water problems within a watershed context. In this manner, they hoped to take into consideration all the factors that affect water quality, from a geographical perspective. Comprehensive watershed assessment, planning, and management of water resources makes sense, but political boundaries (cities, counties, states) rarely follow watershed boundaries. Indeed, boundaries often follow watercourses, effectively dividing any watershed where this occurs. A case in point would be the Missouri River, a boundary for all the counties along the river within the northwestern Missouri region. Therefore, cooperation and coordination among all of the jurisdictions within any watershed is critical to taking a watershed approach to the solving of problems like nonpoint source pollution. More on this topic appears in Chapter 3.

Concerning this watershed-based approach, segments of the separate watersheds are further subdivided into increasingly smaller "hydrologic units" so that distinct watersheds may be broken into more manageable sizes for study. Watersheds have been assigned identification numbers that are 2-digit, 4-digit, 6-digit, 8-digit, 11-digit, or 14-digits in length. The more digits, the smaller the watershed identified. The watershed approach has been endorsed by leading federal agencies like the Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA). It should be remembered that these watersheds define surface water drainage areas only, and while interacting, groundwater areas and political boundaries are but pieces of the bigger picture of the interrelationships of water supply and water use.

Temporal Aspect of Water Use

Water usage changes with the times. Just a half century ago, per capita water use was lower than per capita water use of Missourians today. Hydropower use has evolved from water wheels turning the stones of grist mills of early Missourians to the large electrical generating plants of today. Bathing, clothes washing, and other occasional uses of water by Missouri's previous generations was nothing compared to the water use demands of the present generation of Missourians who number in the millions. Not only has the demand grown because of population growth, but because of the life styles of today and the anticipated changes of the future that the State Water Plan must consider to do adequate justice to the topic of water use. Greater demands, in each generation, have resulted in efforts to supply ever-greater quantities of finite supplies of water to our population. Not only are there more people using more water, but also more water use per capita in a greater variety of ways.

Acknowledgments

The State Water Plan staff thanks the following people for their guidance and support in the preparation of this State Water Plan report: Stephen M. Mahfood, director of the Missouri Department of Natural Resources, Mimi Garstang, State Geologist and director of the department's Geological Survey and Resource Assessment Division (GSRAD); Mike Wells, deputy director, GSRAD; and Steve McIntosh, director, Water Resources Program within GSRAD.

The State Water Plan staff is grateful for the help of the department's Kansas City Regional Office, under the direction of Jim Macy, for initial identification of water use problems and opportunities in northwestern Missouri. The staff also acknowledges the help of consultant Jerry Edwards, hydrologist; Sharon Hankins (program secretary) and Mubarak Hamed (water resource economist) (GSRAD); numerous staff people from other programs within the department, especially Terry Timmons, Kenny Duzan, and Don Scott of the Public Drinking Water Program, and Becky Shannon, John Ford, and Darlene Schaben of the Water Pollution Control Program.

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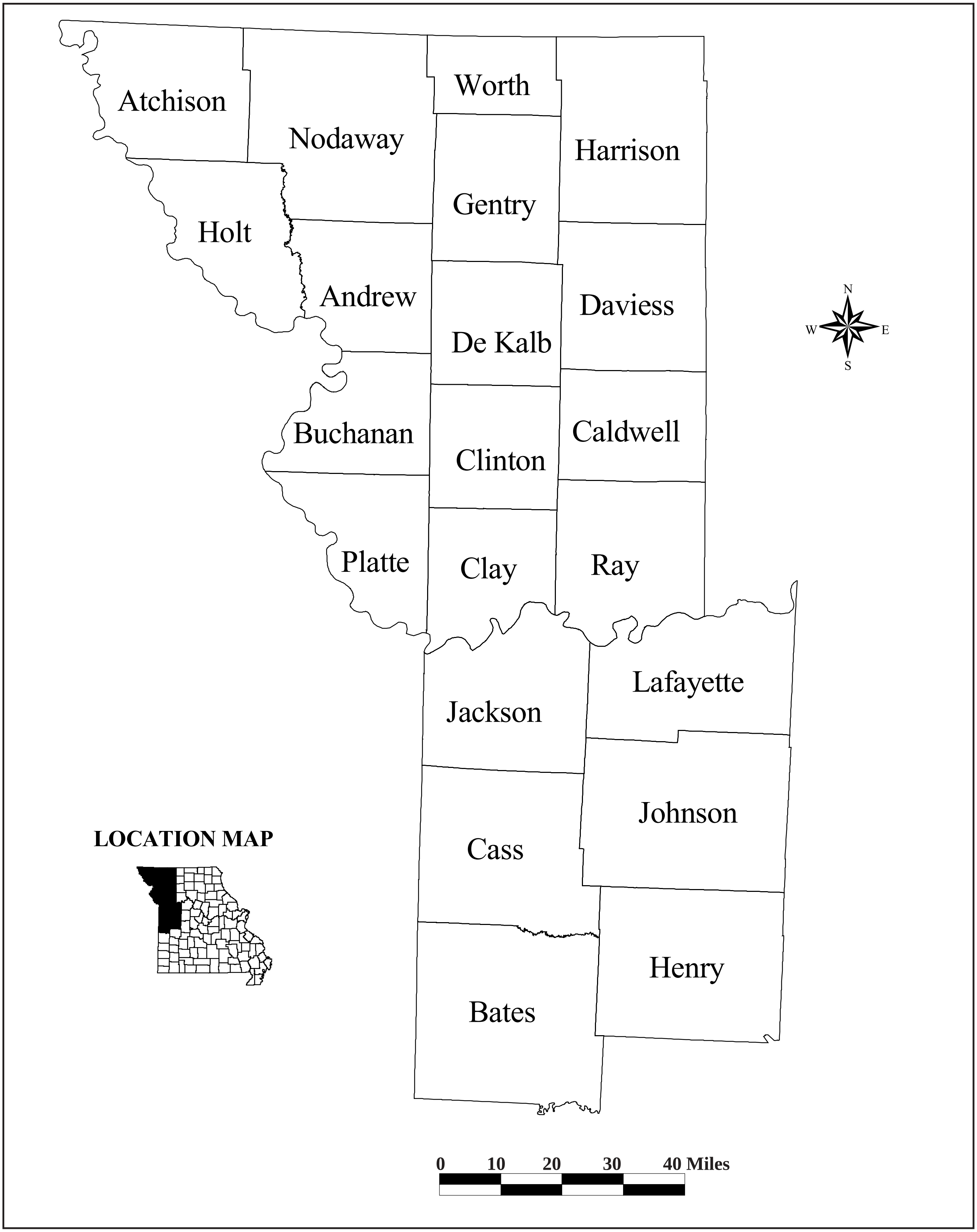

Figure 2. Map showing counties of northwest Missouri region covered by this report.

Regional Description

The Missouri Department of Natural Resources (the department) has six regional offices located throughout the state (figure 1). These offices are designated by the area in which they are located and include the Kansas City, Southwest, Southeast, St. Louis, Jefferson City, and Northeast regional offices. Each office is responsible for issues within a particular area defined on the basis of county boundaries.

Within the jurisdiction of the Kansas City Regional Office are 21 counties in western-northwestern Missouri. These counties are Andrew, Atchison, Bates, Buchanan, Caldwell, Cass, Clay, Clinton, Daviess, DeKalb, Gentry, Harrison, Henry, Holt, Jackson, Johnson, Lafayette, Nodaway, Platte, Ray, and Worth (figure 2).

The State of Iowa forms the northern boundary of the region, and the Missouri River forms the western boundary as far south as Kansas City, from which point, southward, the State of Kansas forms the western boundary. Nine of the 21 counties in the northwestern region front on the Missouri River, a path of commerce since Native American times.

The presence of Kansas City is an overwhelming feature for the northwestern Missouri region. The incorporated territory of Kansas City occupies large portions of Clay and Jackson counties and part of Platte County. This large city and its suburbia are the urban core to the region that otherwise is very rural in character. The dichotomy between the very urban core and the very rural area surrounding it is significant.

Colleges and Universities

Fifteen colleges and universities are situated in the counties of the northwestern region, mostly in the larger cities. The list includes, alphabetically, Avila College, Kansas City (Jackson Co.); Central Missouri State University, Warrensburg (Johnson Co.); Cleveland Chiropractic College, Kansas City (Jackson Co.); DeVry Institute of Technology, Kansas City (Jackson Co.); Longview Community College, Lee's Summit (Jackson Co.), Maplewood Community College, Kansas City (Clay County), Metropolitan Community College, Kansas City (Jackson Co.); Missouri Western State College, St. Joseph (Buchanan Co.); Northwest Missouri State University, Maryville (Nodaway Co.); Park University, Parkville (Platte Co.); Penn Valley Community College, Kansas City (Jackson Co.); Rockhurst College, Kansas City (Jackson Co.); the University of Missouri at Kansas City (Jackson Co.), and William Jewell College, Liberty (Clay Co.) (figure 3). There also are branches of other colleges that offer courses in the region.

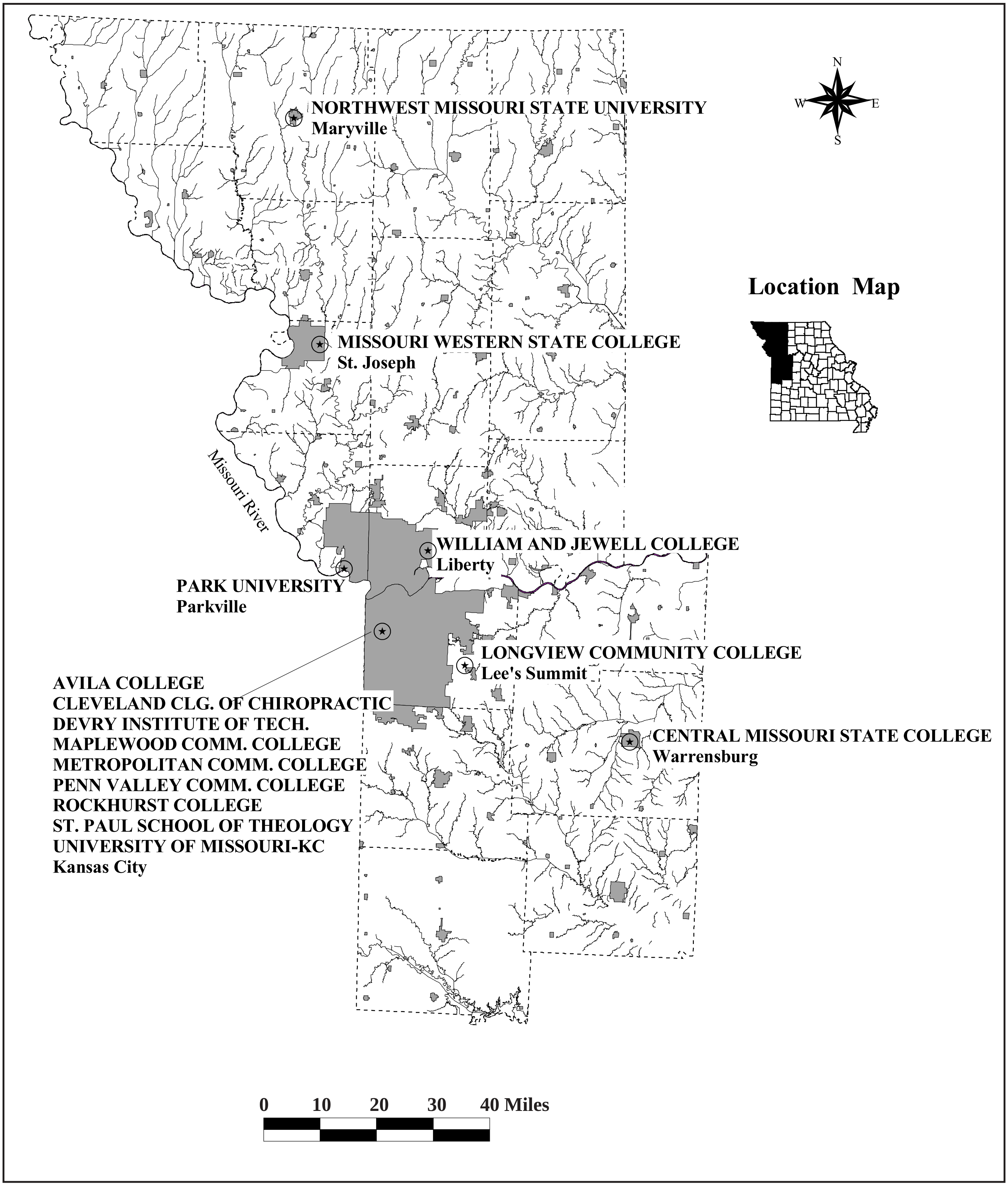

Figure 3. Locations of colleges and universities in northwest Missouri.

Regional Transportation

Navigation

River transportation in the northwestern region of Missouri is entirely by way of the Missouri River. Port authorities in the region are the St. Joseph Regional Port Authority and the Kansas City Port Authority. Numerous private facilities can be found along the river (figures 4 and 5). The St. Joseph Port Authority, in 2001, completed construction of a $1,000,000 development project (with 20 percent local match to a Missouri Department of Transportation (MoDOT) grant) for this intermodal port facility. Truck and rail service to the port gives true multimodal capability (Martin, 2001).

The Kansas City Port Authority handles many tons of commodities annually. Inbound products include such things as bulk fertilizer, tanning salt, steel coil and re-bar, cement clinkers, and decorative rock. (Amounts and values of these commodities constitute proprietary information, and may not be made public.) The port operator of the Kansas City Port Authority is the Midwest Terminal Company. They do not ship outbound by barge. Towboat operators take cleaned, emptied barges from the port to the various private grain terminals in the region where they are loaded with grain for export (Clemens, 2001). The Kansas City Port also is a true multimodal terminal with on-site rail service.

Kansas City is a hub for barge, rail, air and truck shipping for raw, semi-finished, and finished commodities. Ports within the northwest region interconnect with ports upstream, e.g. Omaha, Nebraska, and Sioux City, Iowa, and with the downstream ports of Howard / Cooper County Regional Port Authority, Boonville; St. Louis, and New Orleans in handling both imports and exports.

Railroads

Passenger rail transportation via Amtrak has two trunk lines across the northwestern Missouri region. One route is from Kansas City northeastward to Chicago by way of LaPlata, Missouri. In the other direction, the destination is the west coast. The other route is east-west between Kansas City and St. Louis via the State Capitol, with connections from the two terminals. This route includes stops at Warrensburg, Lee's Summit, and Independence within the region, with two trains a day in each direction.

There are numerous rail freight service lines in the northwestern region of Missouri. Among the Class 1 railroads operating here are the Burlington Northern – Santa Fe (BNSF), the Norfolk Southern Railway (NS), the Union Pacific (UP), and the Kansas City Southern Railway (KCS). Among the Class 2 railroads are the Gateway Western Railway (GWWR) [a subsidiary of KCS], the regional Missouri & Northern Arkansas Railroad (MNA), the I&M (for Iowa and Missouri) Rail Link (IMRL) [formerly the Soo Line], and the inactive Missouri Central Railroad (on the former Rock Island Line purchased by the UP) (figures 4 and 5).

Kansas City and the Kansas City Southern Railway Company are building a huge truck-train intermodal rail hub, called the Kansas City International Freight Gateway. Shipments to and from Mexico will constitute most of the international traffic in the near future. After Chicago, Kansas City already is the second largest rail hub in the U.S.A., and this effort will make it larger. The facility is located at the former Richards-Gebauer military air base that is now closed for general aviation traffic.

Aviation

The largest airport in the region is the Kansas City International Airport (Platte County). Known locally as KCI, it serves major airlines for passenger and freight for domestic and international flights. KCI is also an important mail and package routing center. KCI handles the most freight of any airport in the nation. There also is a Kansas City Downtown Airport, the premier corporate/business airport in the region. The St. Joseph-Rosecrans Airport is located on the west side of the Missouri River, due to a major river avulsion during the Flood of 1952. Nevertheless, the airport is in Missouri; the state boundary having remained unchanged by the flood. There are numerous other small public and private airports throughout the region.

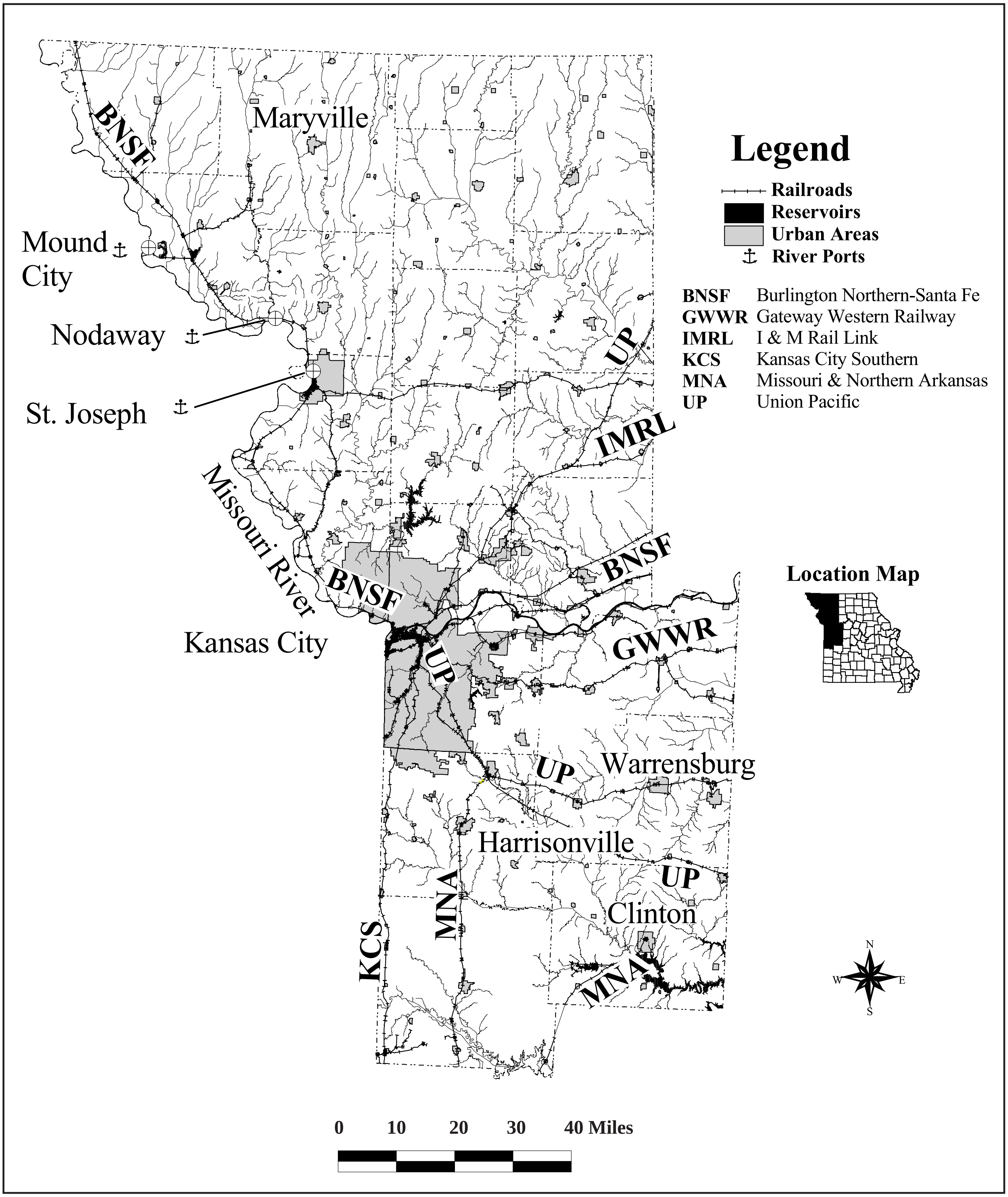

Figure 4. Railways and river ports in northwest Missouri.

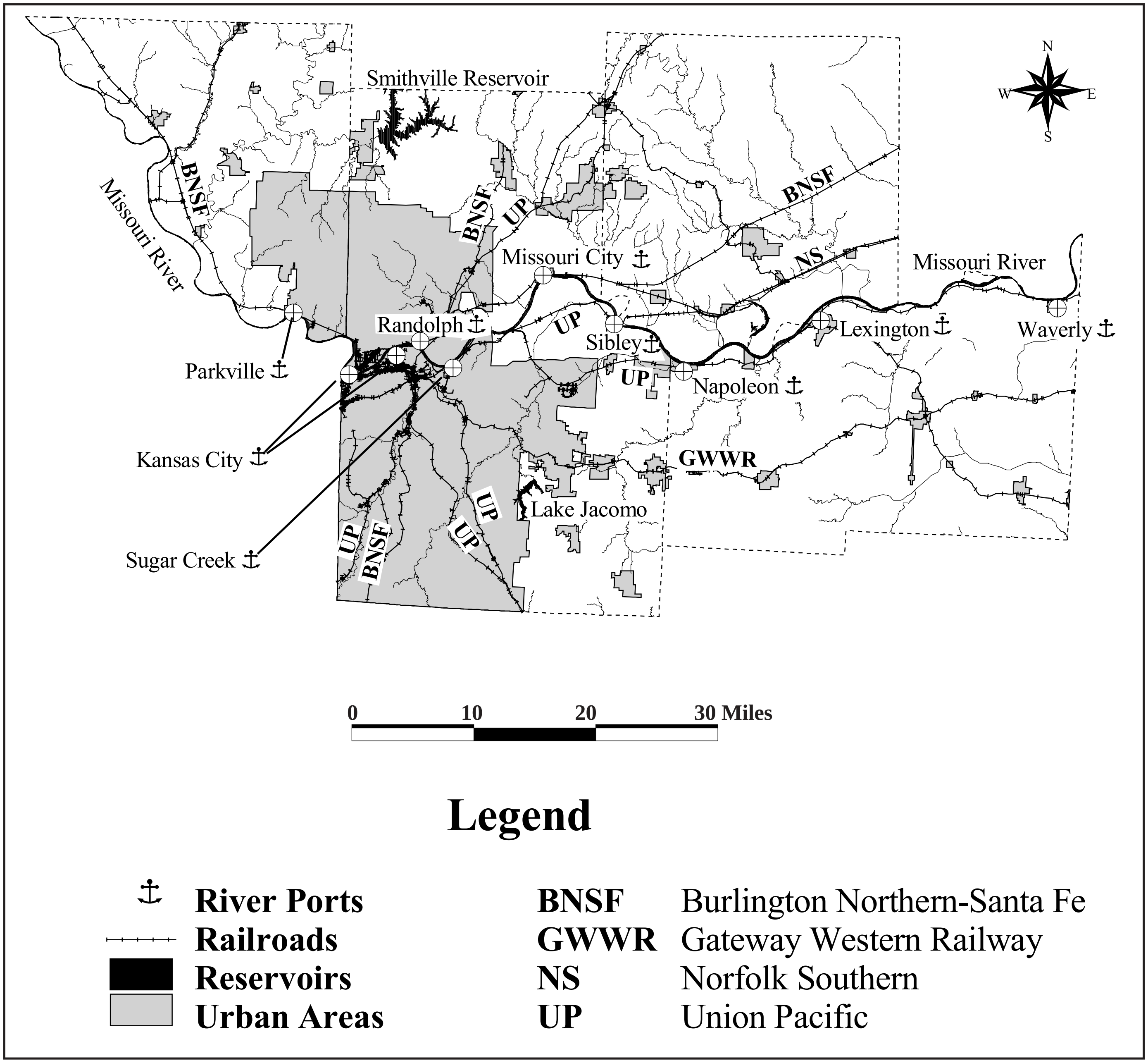

Figure 5. Detail map of railways and river ports around Kansas City.

Highways

U.S. Interstate Highway transportation routes include I-29, east of the Missouri River, northwestward between Kansas City and Council Bluffs, Iowa, by way of St. Joseph; I-35, generally northerly between Kansas City and Des Moines, Iowa, via Cameron and Bethany; I-70, east-west between Kansas City and St. Louis, and beyond in each direction; I-435, circumferentially around greater Kansas City; I-470, in the Independence – Lee's Summit area, and I-635, crossing the Missouri River at Riverside (Platte Co.).

Other major U.S. numbered highways include Route 71, north-south through the northwestern Missouri region; Route 136, east-west across the northern tier of counties; Route 36, east-west through the St. Joseph area of the region; Route 24, east-west across the region just south of the Missouri River; Route 40, roughly parallel with I-70; Route 50, east-west, joining the south side of Kansas City with the Capitol City and beyond in both directions, Routes 59 and 159 in the northwest corner of the region, Route 69 from Kansas City to Lamoni, Iowa, via Excelsior Springs and Cameron, and Route 169, north-south from Kansas City to Iowa. Routes 36 and 50 are mostly four-lane divided highways (figure 6).

Population Characteristics

The 1980 decennial census, when compared to the censuses of 1990 and 2000, shows that parts of the northwestern Missouri region are growing in population while others have a declining population. For the most part, the rural counties are either declining or just holding about steady, while the more urban counties are gaining. Declining are Atchison, Gentry, Holt, Nodaway, and Worth counties. Caldwell has held more or less "steady" over the two-decade span. The rest have gained, with the Kansas City Metro area counties (Cass, Clay, Jackson, and Platte) gaining large numbers.

The largest city in the region, by far, is Kansas City, with nearly 450,000 people. Adding Independence, at nearly 115,000 people, and those of the immediate surrounding area, the metropolitan region holds about three quarters of a million people in Missouri (tables 1 and 2). The greater Kansas City metropolitan area that includes Platte, Clay, Jackson, and Cass counties in Missouri, with Wyandotte (158,000 people) and Johnson (451,000 people) counties in Kansas, totals approximately one and a third million people.

Industry, Commerce and Agriculture

Kansas City has long been considered the agri-business "capitol" of the "breadbasket" region of the United States. Much of the grain shipped to export terminals in New Orleans passes through Kansas City by barge or rail. In fact, it is the second largest rail center in the country, in part due to its central location for shipping agricultural commodities.

Northwest Missouri can generally be characterized as having rolling hills and deep soils. Agriculture is the dominant use and is clearly reflected by the ways the land is managed. Crop hay fields and pasture are interspersed with smaller brush and wooded areas. Compared to other areas of Missouri, such as the Bootheel or Ozarks, one immediately notices the miles of fencing, which illustrates the high productivity of this region's soils, historically smaller sized farms, and the crop-to-grazing rotational farming practices. Land adjacent to larger rivers and streams is relatively flat, contains good soil and almost exclusively is used to grow row crops.

Agriculture plays an important role in the economy of the northwest region, with sales totaling $984 million in 1997 (OSEDA, 2001). The primary crops (with percent of states' total production) in the region in 1997 were corn (34.3 percent), soybeans (30.8 percent), hay (19.9 percent), and wheat (8.3 percent). As of 2000, corn grown in the region was down to only 31.5 percent of the state's total, but the production figures were 60 percent greater than the 1999 numbers, and 2000 was the record high year for corn in Missouri (records going back to 1919). Soybeans were 28 percent, but production was 19 percent greater than the 1999 numbers. Hay was 18 percent, 8 percent less than the previous year. The record high year for hay production was 1998.

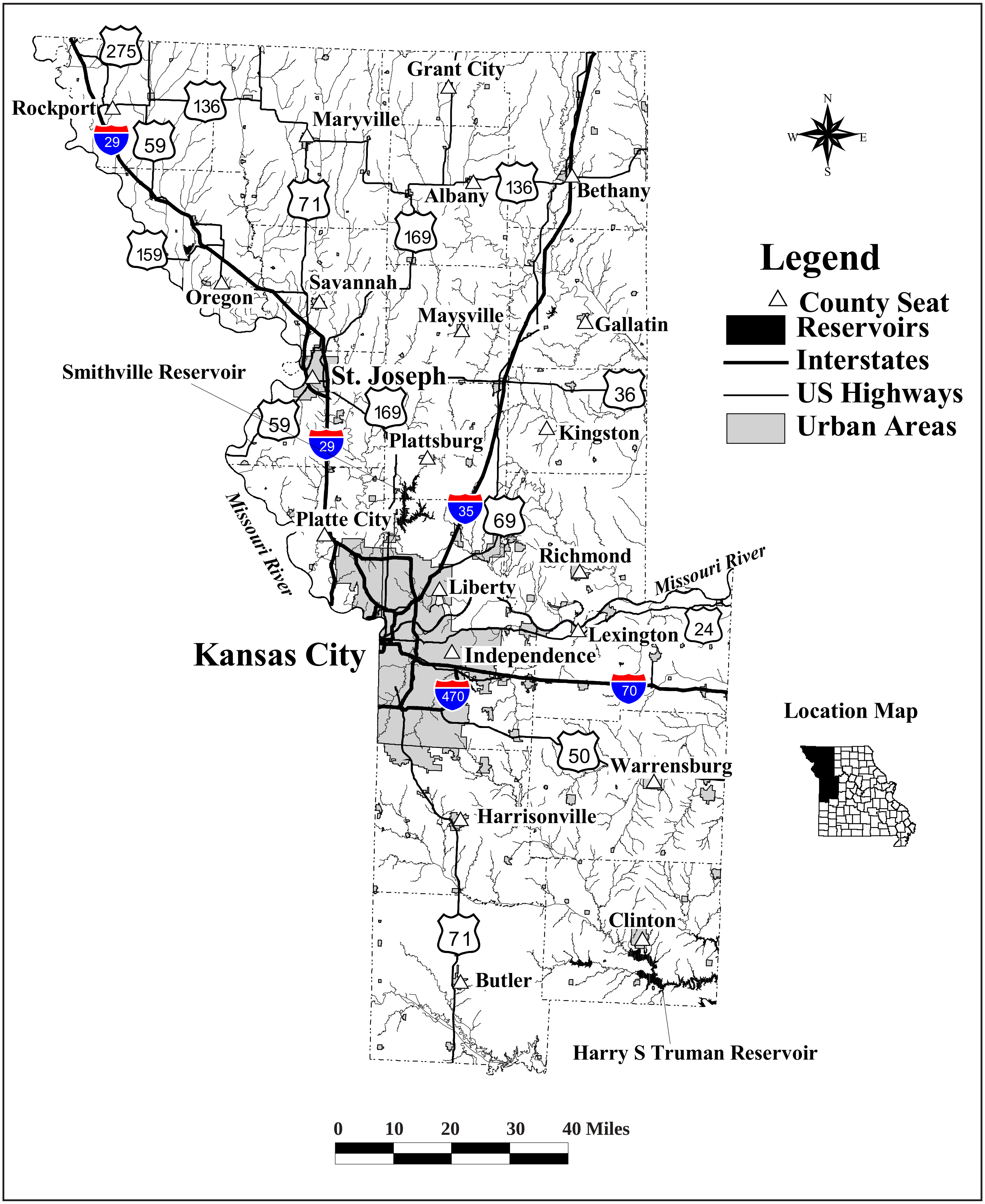

Figure 6. Major roads and cities in northwest Missouri.

County Name	County Seat	Major Town(s)	River Port(s)
Andrew-16,492	Savannah-4,762		
Atchison-6,430	Rock Port-1,395	Tarkio-1,935	
Bates-16,653	Butler-4,209		
Buchanan-85,998	St. Joseph-73,990		St. Joseph-73,990
Caldwell-8,969	Kingston-287	Hamilton-1,813	
Cass-82,092	Harrisonville-8,946	Belton -21,730	
		Raymore-11,146	
		Pleasant Hill-5,582	
Clay-184,006	Liberty-26,232	Gladstone-26,365	Missouri City-295
		Excelsior Springs-10,847	Randolph-45
		Smithville-5,514	
		Kearney-5,472	
Clinton-18,979	Plattsburg-2,354	Cameron-8,312	
Daviess-8,016	Gallatin-1,789		
DeKalb-11,597	Maysville-1,212		
Gentry-6,861	Albany-1,937		
Harrison-8,850	Bethany-3,087		
Henry-21,997	Clinton-9,311	Windsor-3,087	
Holt-5,351	Oregon-935	Mound City-1,193	
Jackson-654,880	Independence-113,288	Kansas City -441,545	Kansas City -441,545
		Lee's Summit-70,700	Sugar Creek -3,839
		Blue Springs-48,080	Sibley-347
		Raytown-30,388	
		Grandview-24,881	
Johnson-48,258	Warrensburg-16,340	Holden-2,510	
		Knob Knoster-2,462	
Lafayette-32,960	Lexington-4,453	Odessa-4,818	
		Higginsville-4,682	Waverly-806
		Napoleon-208	
Nodaway-21,912	Maryville-10,581		
Platte-73,781	Platte City-3,866	Riverside-2,979	
		Parkville-4,059	
Ray-23,354	Richmond-6,116		
Worth-2,382	Grant City-926		

Regional Population = 1,339,818

Source: Census Bureau website: www.census.gov, June 2001

Table 1. Northwestern Missouri region counties and their population.

	1990		2000	
population of region	1,232,458		1,339,818	
population per square mile	104.9		114.0	
number of rural residents	251,716			
population younger than 20 years old[1]	353,280	28.7%	344,455	25.7%
population between 20 and 39 years old[1]	397,038	32.2%	527,547	39.4%
population between 40 and 64 years old[1]	318,900	25.9%	293,243	21.9%
population 65 years old or older[1]	163,240	13.2%	169,296	12.6%
median age	33 yrs., 4 mos.		35 yrs., 6 mos.	
number of households	478,585		530,386	
median household income	$27,912		$40, 916	
number of people below poverty level	146,739	11.9%	134,441	10.0%
total persons aged 25+ with less than a 9th grade education	61,205		38,933	
total persons aged 25+ with a 9th to 12th grade education	104,959		97,053	
total persons aged 25+ with a high school diploma	280,468		289,677	
total persons aged 25+ holding undergraduate degrees	134,907		172,954	
total persons aged 25+ holding graduate degrees	46,991		63,273	
Unemployed	38,324	6.1%	33,152	4.8%
population employed in management and professional occupations	140,361	22.3%	207,368	30.1%
population employed in technical, sales or administrative occupations	199,521	31.7%	183,541	26.7%
population employed in service occupations	80,735	12.8%	97,877	14.2%
population employed in farming, forestry or fishing	14,933	2.4%	2,717	0.4%
population employed in other occupations	156,402	24.8%	163,626	23.8%
Total available workforce	630,276		688,281	
number of housing units	528,223		573,525	
average home value	$55,754		$87,789	

Note: At the time of publication, the complete census data for 2000 was not yet published.
[1]The age breakdowns for the 2000 census were: under 18 years old, 19-44 years old, 44-65 years old, and over 65 years old.

(Source: U.S. Department of Commerce, Bureau of the Census, www.census.gov, October, 2001.)

Table 2. Summarized census data for northwestern Missouri counties.

Wheat was up to 11 percent of state production, 12 percent greater than the 1999 production (MASS, 2001).

Among the 21 counties, four of the state's top ten corn-growing counties are in this region: Atchison ranks 3rd, Nodaway ranks 4th, Lafayette ranks 5th, and Holt ranks 6th. Similarly, three of the state's top ten soybean-growing counties are in this region: Atchison ranks 5th, Nodaway ranks 6th, and Holt ranks 10th. Among wheat-growing counties in this region, Bates County ranks 8th in the state. Among hay-growing counties in this region, Johnson County ranks 3rd in Missouri. Hay is the most widely produced crop in Missouri, ranking 3rd in total value in the state, although normally only about 10 percent of the hay is sold on the market with the rest being used on the farms (MDA, 2001). Sorghum also is grown in the region, with the 2000 crop coming in at 13 percent greater than the 1999 crop. Henry County ranked 9th in the state in sorghum grain production.

Over 80 percent of Missouri's tobacco is grown in Buchanan, Clinton, and Platte Counties. Nevertheless, the regional total and the state total both have declined markedly since 1999:

Buchanan, 870,000 lbs., 1999, and 530,500 lbs. in 2000, 39 percent less than the previous year.

Clinton, 83,800 lbs., 1999, and 49,000 lbs. in 2000, 41.5 percent less than the previous year.

Platte, 2,898,000 lbs., 1999, and 1,818,000 lbs., in 2000, 37 percent less than the previous year.

State Total, 4,635,000 lbs., 1999, and 2,968,000 lbs., in 2000, 36 percent less than the previous year's total. The center of tobacco growing in the region is Weston, Missouri.

The region contains 22 percent of the states' orchards, with Lafayette the second highest county in Missouri. In 1997, 15 of the 21 counties had higher crop sales than that of livestock. Although only a moderate producer of livestock, the region had 18 percent of Missouri's cattle, and produced 7.5 percent of the state's dairy products in 1997. As of 2001, the region held about 10 percent of the state's beef cattle. Bates County ranked 5th, Johnson County ranked 8th, and Nodaway County ranked 9th in the state in numbers of beef cattle. As of January 1, 2001, there were only 150,000 head of milk cows in Missouri, a record low number, with records going back to 1867.

Jackson County was the 9th highest county at producing sheep and lambs in the state in 1997. The number of sheep in Missouri on January 1, 2001, was 73,000, also a record low (records dating to 1867). And the lamb crop of the year 2000 was only 65,000, another record low. Wool production in 2000 was 430,000 lbs., also a record low figure. This may be due to the fact that the price of raw wool per pound has declined markedly: 1997, 45 cents; 1998, 33 cents; 1999, 14 cents, and 2000, only 10 cents per pound.

Kansas City is one of the centers of the stock market trading business of the nation. Many firms trading on the New York Stock Exchange and the Chicago Commodities Exchange have their corporate offices in Kansas City. Hallmark, Interstate Bakeries, Utilicorp (natural gas), and Farmland Industries are all Fortune 500 companies located in the Missouri part of the Kansas City Metro area.

A sampling of Kansas City's industry follows: among food processing industries, Redi-Cut Foods prepares packaged salads for chain restaurants. In manufacturing, there is a Ford assembly plant at Claycomo, and Harley-Davidson Motorcycles. In pharmaceuticals, there are Pfizer and Quintiles. In addition, there are National Starch, American Century mutual funds, and H&R Block.

Physical Characteristics

Northwestern Missouri has a humid, continental climate with average annual temperatures from about 52° F to 55° F. Long term annual precipitation averages from 35 to 38 inches throughout the region (figure 7). Rainfall amounts are generally highest in the spring and lowest in the fall and winter months. Evapotranspiration, the process of precipitation being returned to the air through direct evaporation

or transpiration of plants, consumes from 27 to 29 inches of annual rainfall. Surface runoff of precipitation averages from five to nine inches annually.

Northwestern Missouri lies mostly in the glaciated plains and Osage plains of the Central Lowlands physiographic province (figure 8). During the last period of glaciation, called the Wisconsin glaciation, the exposed rocks of northern Missouri, eroded by earlier glacial advances, were scoured again by advancing ice sheets. The farthest reach of the ice is shown in figure 9. The result of the glacial scouring is a combination of pre-glacial and postglacial eroded surfaces.

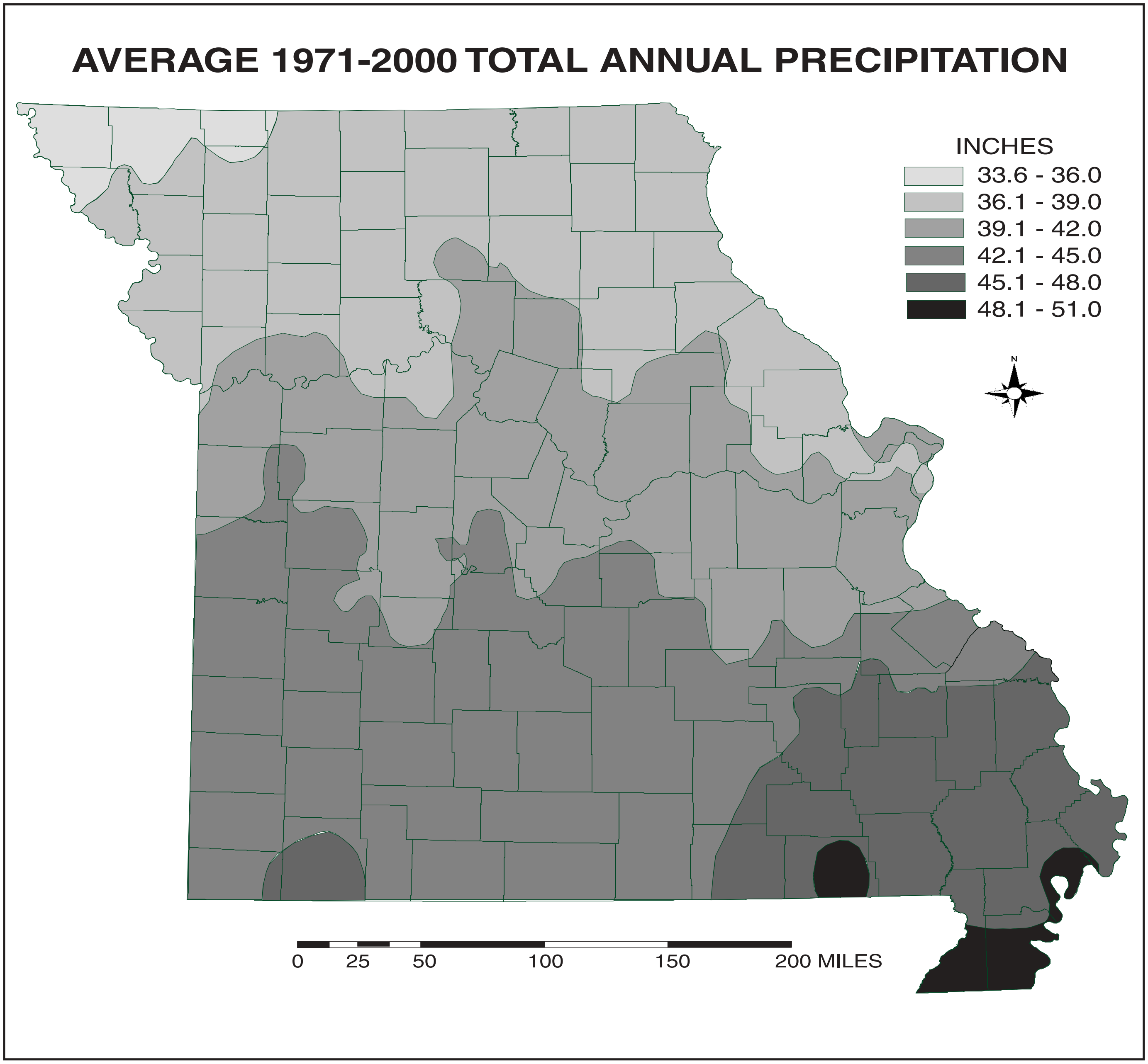

Figure 7. Missouri average annual precipitation from 1971 – 2000. Source: Office of State Climatologist, University of Missouri-Columbia.

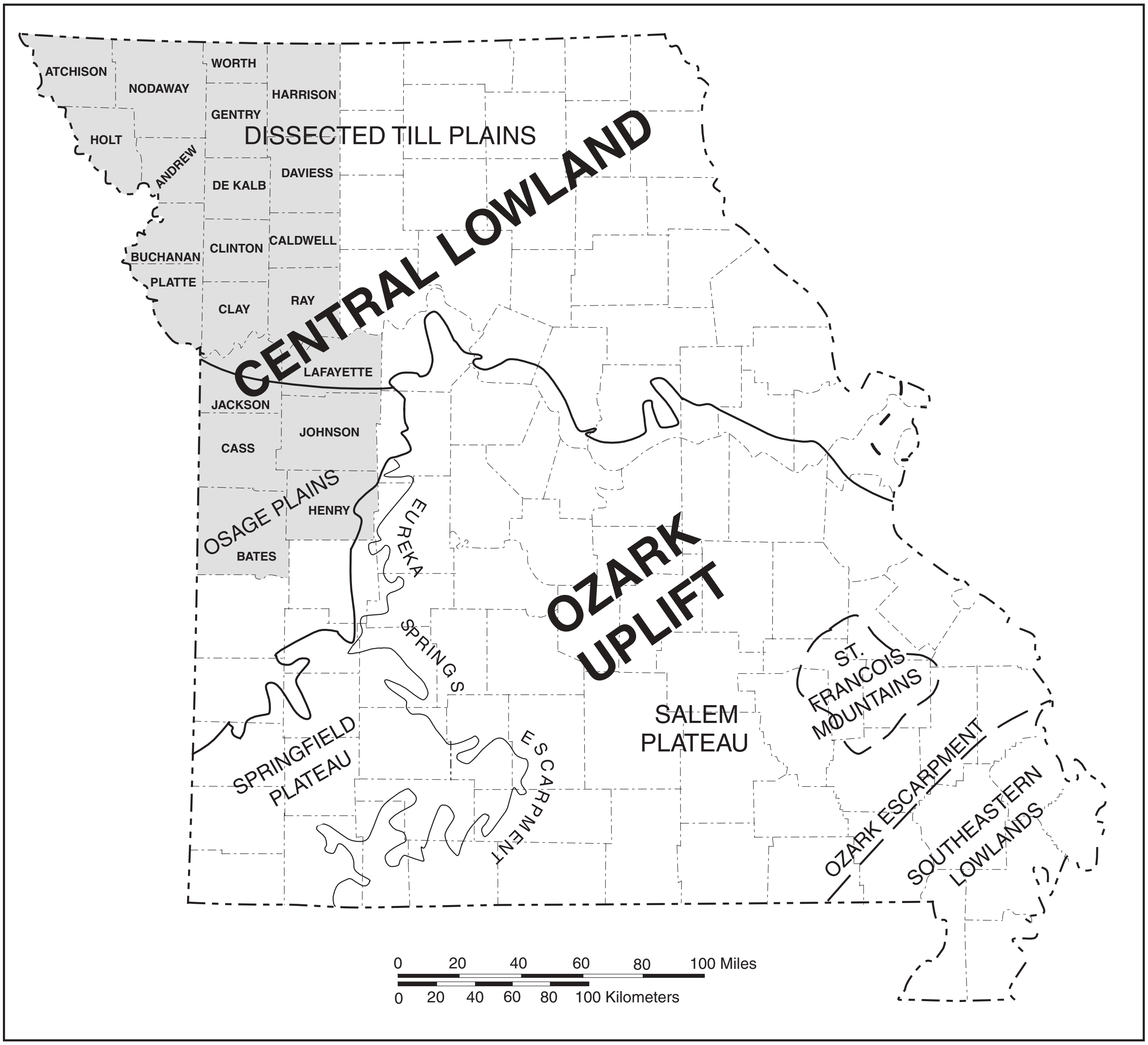

Figure 8. Physiographic provinces of Missouri. Source: Missouri Department of Natural Resources' Geological Survey and Resource Assessment Division.

Glacial till or drift, composed of sand, clay, silt, gravel, cobbles, and boulders, deposited on the surface and in valleys that were eroded earlier, can be quite thick, up to several hundred feet (Brookshire, 1997). These glaciated plains and glacial till are constantly being eroded by rainfall and dissected by runoff, gradually destroying the formerly nearly level topography.

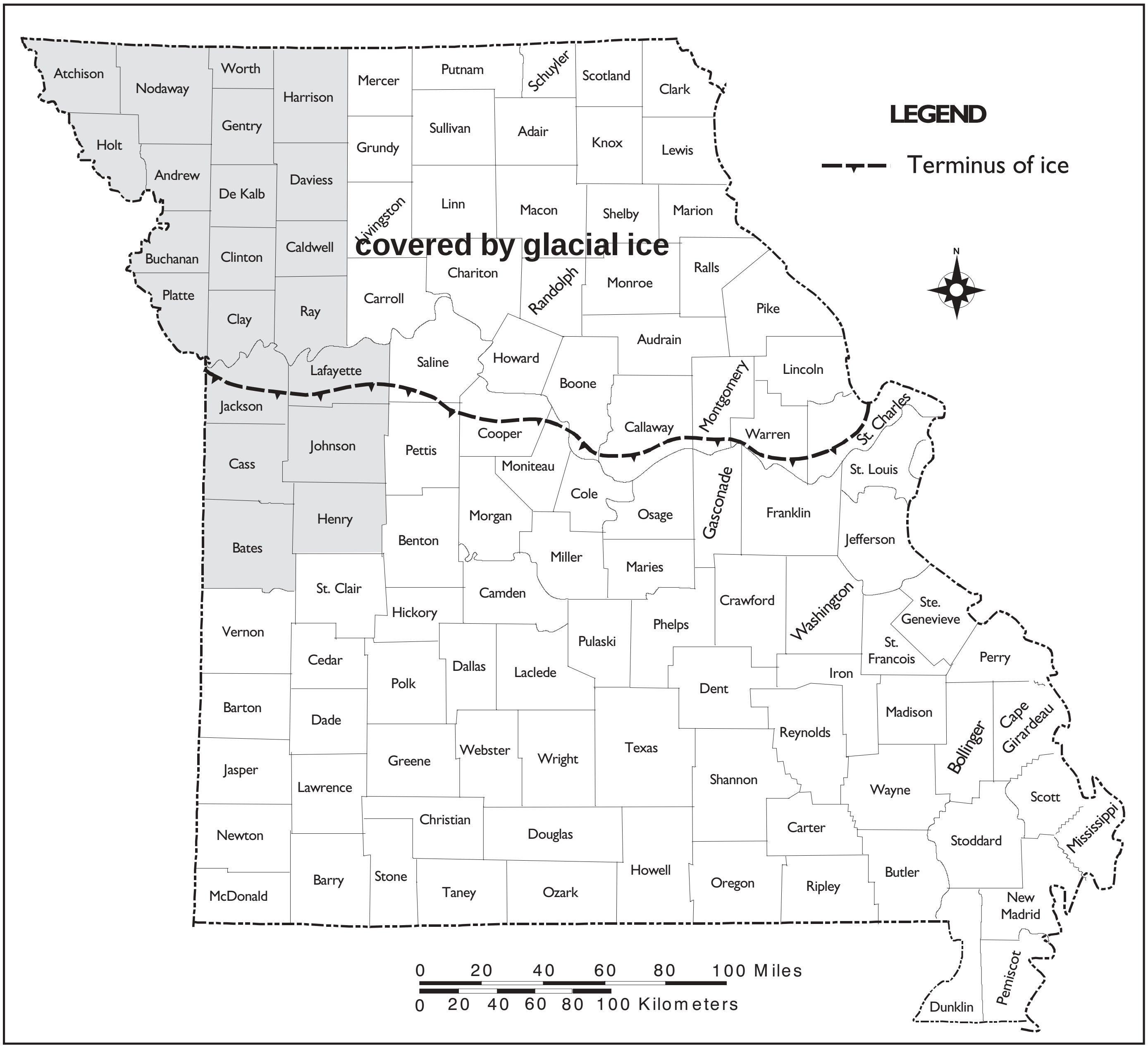

Figure 9. Approximate extent of glacial ice in Missouri.

The drainage pattern consists of nearly parallel streams trending north-south toward the Missouri River, the major drainage stream. The glacial till deposits in pre-glacial valleys can be a good source of water resources. Many of the wells of this region tap groundwater in glacial till deposits (figure 10).

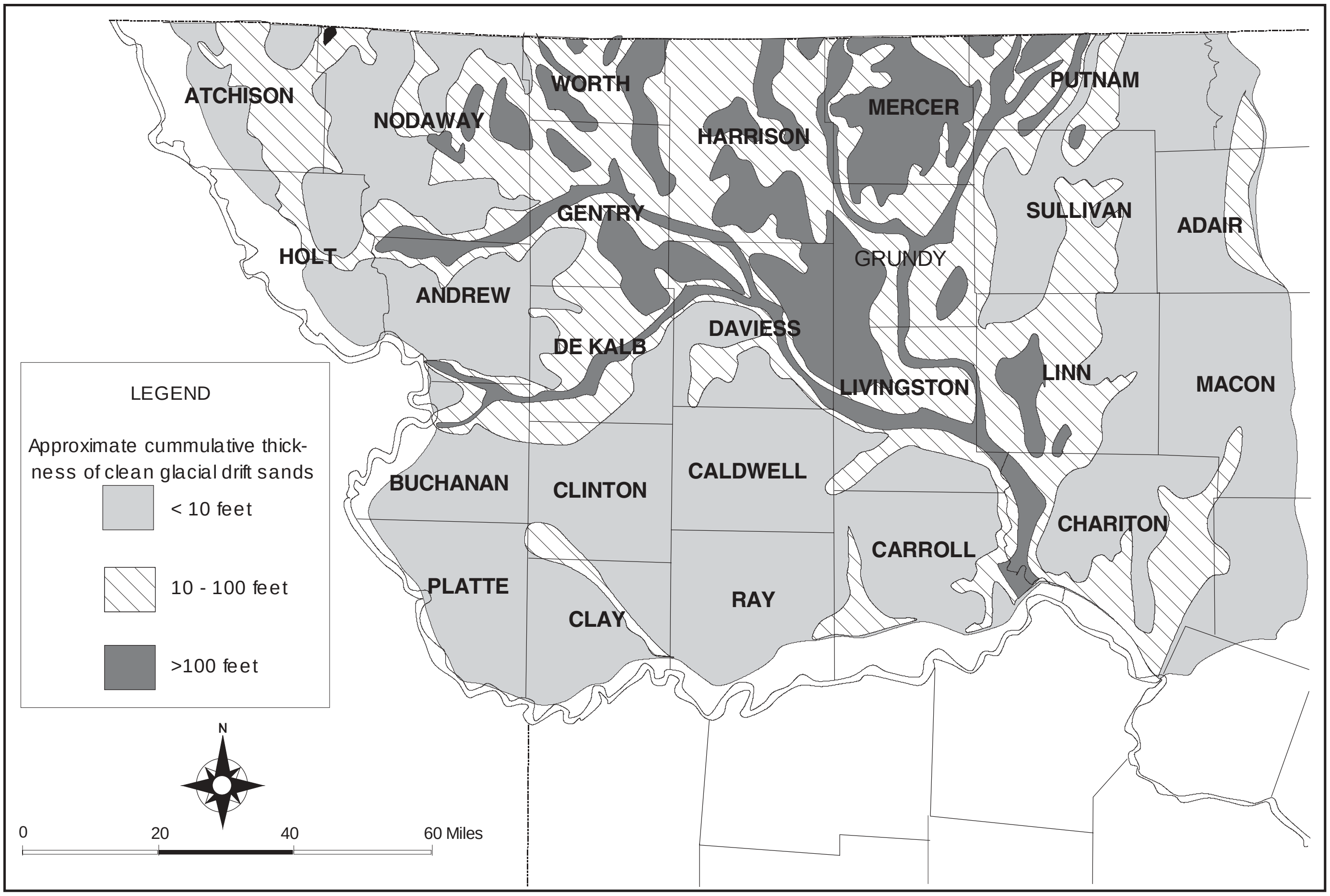

Figure 10. Groundwater possibilities of the glacial drift in northwestern Missouri.

The glacial drift aquifers, especially the buried glacial channels as shown in figure 10, are very important water resources, because deeper groundwater is full of dissolved minerals from the underlying sedimentary rocks of Pennsylvanian age. These strata were laid down when a shallow sea covered Missouri. The deeper groundwater, therefore, generally is high in sodium and chloride, and not considered good drinking water for that reason. Nearly the entire northwestern region of Missouri lies within the saline groundwater province of the state (figure 11).

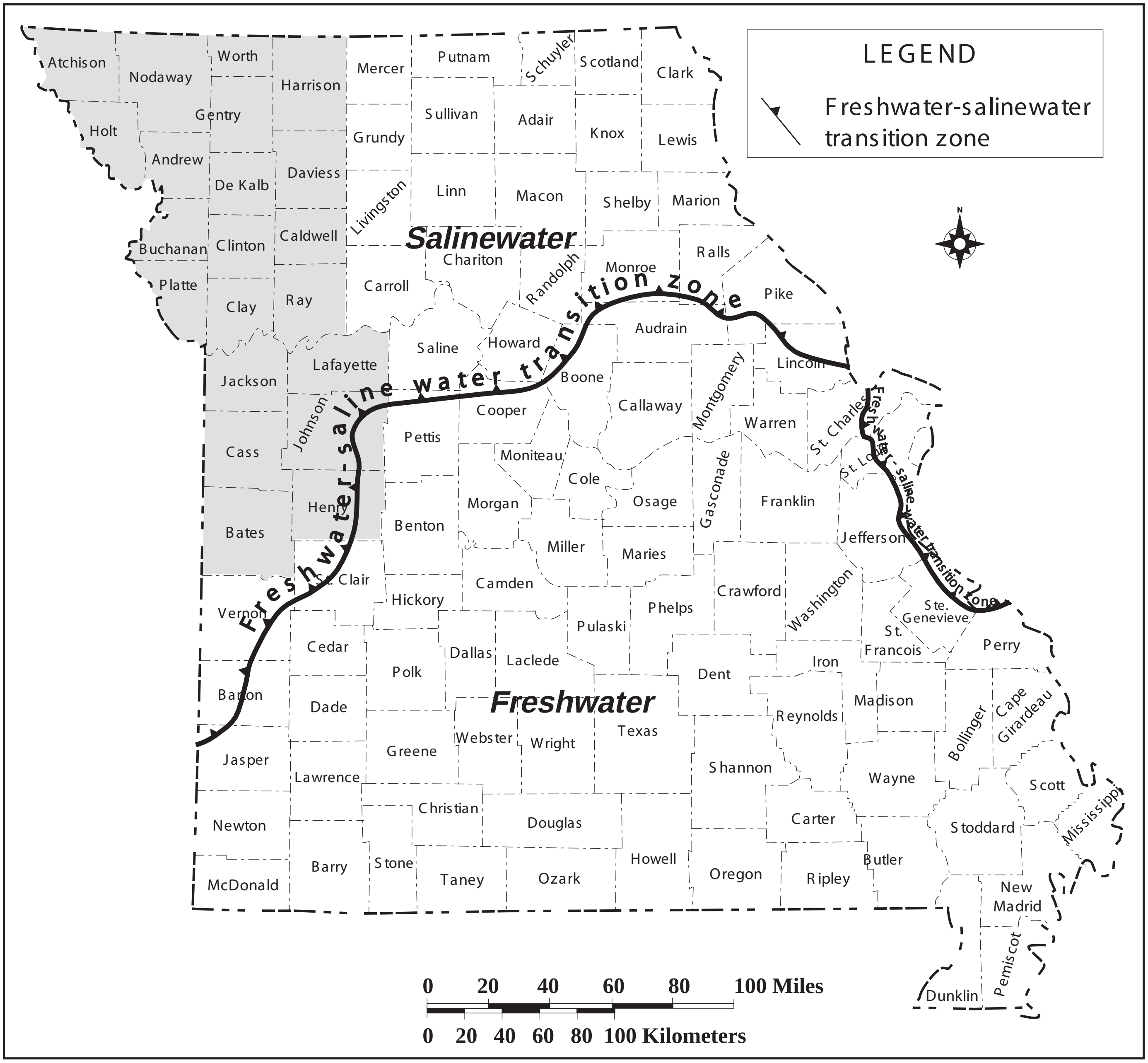

Figure 11. Freshwater-salinewater transition zone. Source: Missouri Department of Natural Resources' Geological Survey and Resource Assessment Division.

Water stored in the flood plain deposits of the Missouri River and other streams is called alluvial groundwater. These deposits are typically very good sources of drinking water and alluvial wells generally yield large quantities of water. In recent years, the water company that serves the City of St. Joseph drilled a well field in the alluvium near Amazonia in Andrew County to provide a reliable source of drinking water for St. Joseph residents. Formerly, the city depended on Missouri River water that was occasionally interrupted by summer droughts or winter ice dams. Kansas City also takes most of its water supply from alluvial wells (figure 12).

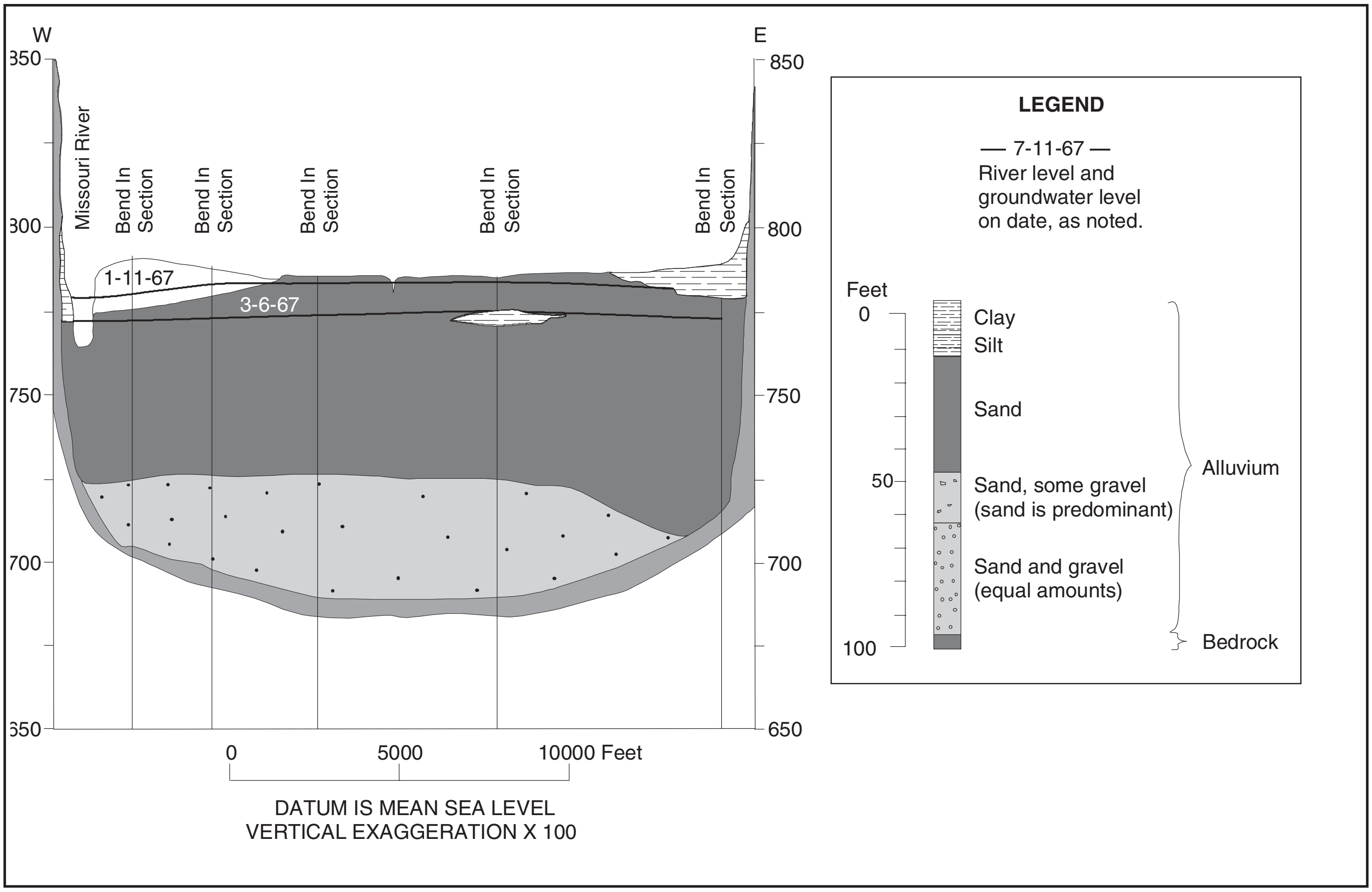

Figure 12. Cross section of the Missouri River alluvium near St. Joseph, Missouri. Source: Emmett and Jeffery, 1969.

In the glaciated area, particularly near the Missouri River, post-glacial winds carried large quantities of fine silt into the air, subsequently depositing it in the "river hills." These deposits are a noticeable characteristic of the landscape along I-29 from Kansas City to Iowa. The silty material, deposited in wind-blown drifts (like sand dunes, but finer-grained), is called loess. Because of the way the silt particles were wind-deposited, the particles are "stacked" vertically, and when these deposits must be excavated, as in road-building, the road cuts are typically vertical, rather than sloped, to reduce erosion by stormwater runoff.

In the unglaciated Osage plains, groundwater resources are meager and mineralized. Most water districts in this area use surface water resources. The presence of Harry S Truman Reservoir is a water supply opportunity for residents of this region of Missouri. The parts of Henry and Johnson counties that lie outside the saline groundwater province have water resources that are not heavily mineralized.

Recreation

The gentle hills, rivers and lakes in northwestern Missouri provide a scenic backdrop for ten state parks and historic sites, and numerous conservation and wildlife areas (table 3). All types of water recreation, including fishing, sailing, swimming, canoeing, water-skiing, and motor boating are available on the area's reservoirs (primarily Smithville and Truman), although not as many choices exist as in the southern part of the state. In addition, several natural lakes also provide opportunities for recreation, including Big Lake (Holt Co.), Lewis and Clark Lake (Buchanan Co.), and Bean Lake (Platte Co.), all of which are found in the flood plain of the Missouri River.

County	State Parks[1]	MDC[2]	Federal[3]
Andrew	0	14	0
Atchison	0	8	0
Bates	0	7	0
Buchanan	1	17	0
Caldwell	0	2	0
Cass	0	5	0
Clay	1	5	1
Clinton	1	2	0
Daviess	0	7	0
DeKalb	0	0	0
Gentry	0	3	0
Harrison	0	5	0
Henry	0	8	1
Holt	1	8	1
Jackson	2	17	4
Johnson	1	5	1
Lafayette	1	9	1
Nodaway	0	7	0
Platte	1	7	0
Ray	1	10	1
Worth	0	4	0

Sources: [1]www.dnr.state.mo.us/dsp/index.html; [2]www.conservation.state.mo.us; [3]www.fws.gov/; [3]www.usace.army.mil/; [3]www.nps.gov/; [3]www.af.mil/

Table 3. Number of state and federal recreational facilities in northwestern Missouri.

Sources:

Brookshire, Cynthia, 1997, Water Resources Report Number 47, ***Missouri water quality assessment,*** Missouri State Water Plan Series Volume III, Missouri Department of Natural Resources, Division of Geology and Land Survey.

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Missouri Department of Agriculture, 2001, ***Missouri agriculture, a statistical snapshot,*** MDA Annual Report, 36 p.

Office of Social and Economic Data Analysis (OSEDA), 2001, available on line at www.oseda.missouri.edu

Regional Water Use Overview

The following description of water use in northwestern Missouri is included to provide context for the water use problems identified in this report. The categories used below are the same as those used by the United States Geological Survey (USGS) in the National Water-Use Information Program. Most of the water use data provided in this section were collected through this program. Many of the water use problems included in this report address drinking water and industrial issues, demonstrating the importance of those uses to the region. Domestic and industrial applications are the predominant water uses of northwestern Missouri. These uses combined represent 64.2 percent of northwestern Missouri's total water use (excluding power generation) of 207 million gallons per day (USGS, 2001).

Public Water Supply

The percentage of publicly supplied water allocated to commercial and public uses within the region is lower than statewide averages. The percentage of publicly supplied water for domestic use in the northwest region in 1995 was approximately 68 percent compared to 65.2 percent for Missouri statewide (USGS, 2001). Public water use is often defined as community-wide applications of water, such as firefighting and filling public swimming pools. Public water use also includes transmission losses, which is water lost from leaking pipes and joints while being delivered to domestic, commercial and industrial users. Nearly 17 percent of northwestern Missouri's publicly supplied water was delivered for public uses in 1995, compared to 21.8 percent statewide (USGS, 2001).

Similarly, 1995 commercial use of public water supplies was slightly lower in northwestern Missouri than for the state overall. Commercial water use is defined by the USGS as "water for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions" (Solley, et al., 1993). In 1995, approximately 9.4 percent of northwestern Missouri's publicly supplied water was delivered to commercial water users compared to 10.3 percent statewide (USGS, 2001). Public water supply deliveries for industrial purposes in northwestern Missouri, conversely, were lower than the statewide average in 1995. Compared to the statewide figure of 24.4 percent, industrial water users in northwestern Missouri accounted for only 21.8 percent of total public water supply usage (USGS, 2001).

Some 54 percent of the population of northwestern Missouri receiving water from public water systems are supplied by groundwater. It is important to note that the majority of this groundwater comes from the Missouri River alluvium in the Kansas City region and near St. Joseph. The Missouri River and a number of small public water supply lakes supply the remaining population. In northwestern Missouri, 87 percent of citizens are connected to a public water supply.

Domestic Water Use

Domestic water use is often defined as "water used for household purposes," such as drinking, cooking, bathing, and washing clothes and dishes. Excluding thermoelectric and hydroelectric power generation, domestic water use is the predominant use of water in northwestern Mis-

souri. The National Water-Use Information Program of the United States Geological Survey (USGS) estimated 1995 domestic water use (deliveries + withdrawals) in northwestern Missouri at 34.2 billion gallons of water. USGS figures indicate that per capita usage was approximately 75.6 gallons/day for public supply domestic usage. However, self-supplied per capita use was only 60.0 gallons/day. While 89 percent of northwestern Missouri's domestic water requirements are supplied by public water systems, the rest is self-supplied. However, these numbers are slightly biased in that the Kansas City metro area (with near 100 percent public supply) is a large percentage of the population, whereas rural areas have a lower percentage on public supply. For example, Harrison County has only 78.3 percent of the population on public water systems. Approximately 164,000 people in northwestern Missouri drew water from private supplies in 1995 (USGS, 2001). USGS data from 1995 indicate that 100 percent of self-supplied domestic water withdrawals came from groundwater sources, although it is likely that a fraction of a percent of users obtained water from surface water sources. In the 1990 U.S. Census of Population and Housing, approximately 5,057 housing units in northwestern Missouri reported using "some other source" for water, a catch-all category which the Census Bureau defines as "water obtained from springs, creeks, rivers, lakes, cisterns, etc."

Industrial and Commercial Water Use

Industrial water use in northwestern Missouri is about the same as the state's average, and accounts for 22 percent of public water supply deliveries. Industrial water use is water used for industrial purposes such as fabrication, processing, washing, and cooling. Industrial water users across Missouri typically rely on public-supplied rather than self-supplied water. In 1995, industrial water users in northwestern Missouri received 9.7 billion gallons of water from public water systems, approximately 68 percent of their total water use (withdrawals + deliveries) (USGS, 2001). In 1995, 56 percent of total self-supplied withdrawals for industrial use came from groundwater sources. USGS data indicate varying levels of industrial water use throughout northwestern Missouri, with 13 out of 21 counties showing no industrial water use at all.

In northwestern Missouri, commercial water use was less than industrial water use. Commercial water use is water used for motels, hotels, restaurants, office buildings, other commercial facilities and institutions. Commercial water use (withdrawals + deliveries) in northwestern Missouri totaled nearly 5.5 billion gallons in 1995, 38 percent of that used for industrial purposes. Commercial water use in northwestern Missouri depends upon both public water supply deliveries and private supplies, with public water systems supplying approximately 76 percent of the region's commercial water requirements (USGS, 2001).

Agricultural Water Use

Farmers in northwestern Missouri withdraw water both to irrigate farmlands and to water their livestock. Irrigation water withdrawal far exceeds water withdrawn for livestock watering in both statewide and northwestern Missouri totals. Groundwater sources account for most of northwestern Missouri's agricultural water withdrawal. In 1995, 60 percent of the 14.2 billion gallons of water withdrawn for all agricultural operations in northwestern Missouri was taken from the region's groundwater (USGS, 2001).

Irrigation water withdrawal in northwestern Missouri surpassed livestock withdrawals in 1995, exceeding 9.5 billion gallons of water. However, ponds and cisterns are not considered, and they are often sources of water for livestock. Approximately 24 percent of irrigation withdrawals in northwestern Missouri came from surface water sources in 1995, in sharp contrast to the statewide value of 6 percent (USGS, 2001). Two thirds of irrigation water withdrawal was in Atchison County, 18 percent in Andrew, Cass, and Holt counties, with the rest of the counties making up the remaining 13 percent.

Three-fourths of livestock water withdrawals were from surface water sources, consistent

with the state as a whole. Livestock production is more evenly distributed across northwestern Missouri, with individual counties withdrawing up to 475 million gallons of water per year (USGS, 2001). A variety of livestock is raised in northwestern Missouri, each of which must have access to water throughout the year. Farmers in northwestern Missouri withdrew slightly more than 4.7 billion gallons of water for their livestock in 1995.

Water Use in Power Production

The Major Water Users Database of the Missouri Department of Natural Resources estimated that the total thermoelectric power generation withdrawals in northwestern Missouri were approximately 404 billion gallons of water in 2000 (Barnett, 2001). Withdrawals for thermoelectric power generation are used primarily for power plant cooling and come almost entirely from surface water sources. Although thermoelectric power generation requires vast amounts of water, very little of it is actually consumed. Statewide, more than 99 percent of all thermoelectric power withdrawals were returned to their source waters. In northwestern Missouri, six facilities (Hawthorne, Sibley, and Trigen in Jackson County; Iatan in Platte County; Lake Road in Buchanan County; and Montrose in Henry County) account for the region's thermoelectric power generation. These thermoelectric plants include coal, petroleum, and gas-fired facilities. There are no hydroelectric power generation facilities in northwestern Missouri.

Other Instream Flow Uses

Fish and other aquatic organisms in northwestern Missouri's lakes and streams depend upon flowing water for survival and aquatic habitat preservation. Many municipalities in the region rely upon flowing water to safely release wastewater back into the environment. River barges on the Missouri River require flows sufficient to permit safe navigation. Although no water is withdrawn, each of these is a "use" of water as well. Collectively, these are often referred to as "instream" uses.

Preservation of aquatic wildlife and habitat is an important "instream" use of water. Most of the region falls within the Prairie Aquatic Faunal Region, with sections along the Missouri River falling in the Big River Aquatic Faunal region (Pflieger, 1989). Many of the upland drainages may become dry during drought conditions, and even some of the major rivers (i.e. Platte, One Hundred and Two, Tarkio) have had several periods of no flow during drought.

Many communities in northwestern Missouri release treated wastewater into nearby rivers and streams. In 1995, the USGS estimated that the region's rivers and streams assimilated 105.5 billion gallons of treated wastewater (USGS, 2001).

Sources:

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Water Use Problems

DRINKING WATER USE

Public Drinking Water Suppliers

Problem:

Public drinking water suppliers can endanger public health when their water supply does not meet the standards.

Discussion:

The Missouri Department of Natural Resources' Public Drinking Water Program (PDWP) has been charged with assuring that public water systems supply safe and adequate drinking water to their customers. They accomplish this by following the federal Environmental Protection Agency (EPA) and Missouri Safe Drinking Water standards that are designed to ensure that the public health is not threatened by contaminated drinking water. These standards are called Maximum Contaminant Levels (MCL's). They are risk-based concentration units for a set of known contaminants. The supplier samples the water at various points after it has been through the drinking water treatment plant and sends it to approved water quality testing labs to make sure it meets the standards.

If the water fails to meet these standards (MCL's), the PDWP notifies the supplier of the violation and helps them determine how to comply with the standards. The PDWP administers a program to provide loans and grants for capital improvements and technical assistance. Additional treatment may be needed to bring a system back into compliance.

In addition, the PDWP helps the public water supply systems design a Drinking Water Source Water Assessment Plan, whereby the supplier works with local entities (farmers, businesses, etc.) in the region who may be complicating the contamination problem, to get them to initiate practices (e.g. Best Management Practices (BMP), watershed protection practices) which will help address the contaminant problem. First, the sources of possible contamination are identified and located, pursuant to state law. Then the water supplier works with those who own the possible contaminants to prevent possible contamination to surface or groundwater sources. The advantage of the Source Water Assessment Plan is that, by identifying the potential contaminants, such as stored fertilizer within the area of influence for the public water supply, one does not have to test the water for every known contaminant, which would be expensive. The supplier would only be required to test for what has been identified in the assessment. One potential problem with quarterly testing is that a pollution event could occur between the testing periods and thus not be reported for up to three months.

If the supplier is unwilling or unable to comply with the standards (MCL's), the PDWP can take formal enforcement action, including litigation, penalties based on statutory authority, or referral to the U.S. EPA for federal action (MacEachen, 2002).

The supplier is mandated to notify their customers if it is in violation of the standards, but occasionally they do not (MacEachen, 2001). This still leaves the public at risk since they may

still be drinking the contaminated water. Statewide news releases are issued by the department alerting the public of the violation when they are concerned that the public hasn't been properly notified. However, there is no guarantee that the public will understand the notification, nor that they will receive notification in a timely manner. If the department determines that the contaminant poses an acute risk, the supplier in violation must notify the public as soon as possible through television and radio announcements. This is usually accompanied by a recommended action (e.g. water boiling when contaminated with e-coli) (MacEachen, 2001). However, there may be consumers who are not aware of the media announcements, which leaves them in a vulnerable position. They may unknowingly continue drinking contaminated water.

If there is a contamination problem exceeding an MCL, switching to a non-contaminated alternate source of drinking water is the only option that can fully prevent the public health risk. However, this is not always possible due to logistics (e.g. there is no other source of water available) or because of the supplier's financial situation (e.g. it may be too costly to switch water sources).

The supplier is mandated to provide its customers with Consumer Confidence Reports (CCR) once a year. These reports contain the results of water quality tests and report any violations that have occurred within the last year (Missouri Water Resources Law - Annual Report, 2000). The CCRs provide an opportunity for consumers to learn about their drinking water, which can increase their awareness of the quality of the water they consume.

Sources:

MacEachen, John; Environmental Specialist, Missouri Department of Natural Resources, Water Protection and Soil Conservation Division, Public Drinking Water Program. Personal communication, January, 2001.

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Missouri Water Law

Problem:

There is an absence of statutory water quantity law, which would define the entitlement of each water user.

Discussion:

Missouri is a riparian water law state. As such, the laws guiding the quantity of individual and municipal water withdrawal is almost entirely established through court decisions rather than legislated law. The overall guidance that an individual can garner from a comprehensive court case review may be marginal. Under the law, each riparian has the same rights. Following the principles of riparian case law, a riparian landowner has the legally protected right to withdraw a reasonable quantity of water and put it to personal beneficial use. However, the amount withdrawn cannot be so much that it adversely impacts another riparian water user. When the actions of one riparian adversely affect another, it is up to them to either work out a solution with each other or failing that, to bring suit in a court of law to enforce water quantity rights and to seek legal relief and reparation. The state is not typically a party to disputes involving water quantity issues between individual riparian landowners.

Legislated law does not address the quantities of water a riparian can withdraw for use. "There is no body of statutory law in Missouri that addresses quantities of withdrawal of water by riparian tenants" (Gaffney, 2001). Applying to both watercourses and groundwater, Missouri courts, which have addressed water quantity issues, have fairly consistently held that water withdrawal and use issues as well as questions of allowable amounts are an instance-by-instance issue of which the state court system is the sole determiner. Following this line of reasoning, no riparian can be completely sure of exactly how much water he is entitled to withdraw, exactly which beneficial uses are recognized or prioritized, or under what weather, stream flow, or groundwater table conditions can water be withdrawn and avoid the legal liability of "using too much water" (Levi, 1969). The obvious result of these guidelines is that the quantity and the timing of what can be legally withdrawn are ever changing. As demand grows and/or supplies shrink, an individual's legally recognized "reasonable" quantity to which he or she is entitled decreases (Levi, 1969). In times of plentiful supplies, the quantity that an individual can legally use may not be the same as during times of drought.

The northwest area of the state has relatively poor groundwater resources (when compared to other parts of the state), and relies on surface water for most water supply needs (Vandike, 1995). Meteorologically, the northwestern portion of Missouri generally has lower precipitation amounts than the rest of the state, ranging from 34 to 38 inches annually. The average annual runoff is generally between 5 and 9 inches (Miller and Hays, 1995). Surface water sources are supplied predominately from rain and snowfall runoff, and as such the surface water supplies expand and contract following the precipitation patterns. River corridor alluviums are notable resources for greater and more consistent water supplies than are most surface and other types of groundwater sources in the region.

Large quantity water users, like municipalities and industry, have water source options which private individual rural users within the region may not. Cities, towns and industries not only have greater water quantity demands, but also have greater financial resources to secure supplies that will meet their needs. Private individual rural users do not. While the private individual is pretty much limited to drilling their own shallow well or "hooking on" to the local public water supply district, cities, towns and businesses may also have the option of drilling deep wells, tapping alluvial supplies, or constructing reservoirs or surface water intakes along larger streams and rivers. Thus, the users with greater demand and more financial backing can develop their own supply source(s) to meet their needs and thereby, to a certain measure, insure themselves a specific quantity of water. But even then, the quantity they can withdraw is not guaranteed – there is still drought and there are still the unclear limits of riparian water law.

Riparian water rights in Missouri are neither owned nor transferable in the sense that property is owned and transferred. At the same time, each riparian does have legal right to use the water resources, the right to use being attached to land ownership rights. This can be a confusing concept. Similar to air, water is generally recognized in Missouri courts as a non-commodity or free good, to which each person is entitled but no one owns.

Because, under riparian water law, there is no guarantee to the quantity of water that a landowner riparian can use, this can be an economic disincentive to the development of long-term, large quantity water uses. Individuals, agriculture, businesses and industry may be reluctant to invest in an expensive water supply system because they may be legally prohibited from using the system in the future. This also carries with it negative social and environmental impacts: negative social impacts, in that while water is a "free good," only those with the financial means can fully develop the supply sources. This general economic disincentive of water source development may translate into more restricted general economic development. Also, when water is in short supply, as during a drought, environmental needs almost always take a back seat to social and economic needs.

Sources:

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Gaffney, Richard M., Charles Hays, William J. Bryan and Amy Randles, 2000, Missouri State Water Plan Series-Volume VII, ***A summary of Missouri water laws,*** Water Resources Report Number 51, Missouri Department of Natural Resources, Division of Geology and Land Survey.

Levi, Donald R., Spring, 1969, "Highest and best use: an economic goal for water law," ***Missouri Law Review,*** 34:165-177, Columbia, Missouri.

Miller, Don and Charles Hays, 1995, ***Missouri drought response plan,*** Water Resources Report Number 44, Missouri Department of Natural Resources, Division of Geology and Land Survey.

Vandike, James E., 1995, Missouri State Water Plan Series-Volume I, ***Surface water resources of Missouri,*** Water Resources Report Number 45, Missouri Department of Natural Resources, Division of Geology and Land Survey.

Drought Effects

Problem:

Drought effects in northwestern Missouri are especially problematic due to a combination of water supply and water use factors.

Discussion:

Groundwater resources within the region are generally of poor quality. Most groundwater wells outside river corridor alluvia or buried glacial channels (figure 10) yield relatively limited quantities of water even during times of above-normal precipitation. During periods of drought, groundwater quantities, adequate to meet needs, may not be able to be pumped from the shallow water-bearing glacial deposits. Besides the generally poor quantities of shallow groundwater found in the region, the deeper bedrock water-bearing formations of the northwest region lies within the saline-groundwater zone and contains calcium and sodium carbonates, chlorides, and sulfates causing the water to be poor in quality (figure 11).

Broadly stated, the region is more dependent upon surface water than groundwater. Streams in the region are dependent upon precipitation and receive little, if any, appreciable groundwater recharge. Surface water impoundments and larger streams and rivers comprise the greatest sources of substantial quantities of water and are at high risk during drought events. Base flows in streams are dependent upon precipitation. Consequently, the region has numerous man-made impoundments to store water, ranging from small farm ponds to large lakes that are built and maintained by the federal government. During periods of drought, these surface water resources are obviously "lower" than normal. This drought-induced shortage is compounded by the fact that the human demands placed on these already less than normal supplies can increase due to the dry weather. This compound cause-and-effect cycle can lead, and has led in past instances, to severe water shortages.

The surface physical characteristics of most of the northwestern region initially were formed by glaciers that left thick deposits of unconsolidated sediments. The deposits average 100 feet in thickness but can be as much as 300 feet thick. This glacial till, consisting chiefly of clay, silt, sand, gravel and boulders, has been dissected by post-glacial erosion from runoff. Much of the resulting watershed drainage pattern consists of nearly parallel streams that trend from the north to the south and drain into the Missouri River (figure 13).

For the area of northwestern Missouri north of the Missouri River, annual runoff averages 5 inches per year in Atchison County to 7 inches per year in Ray County (figure 14). Average

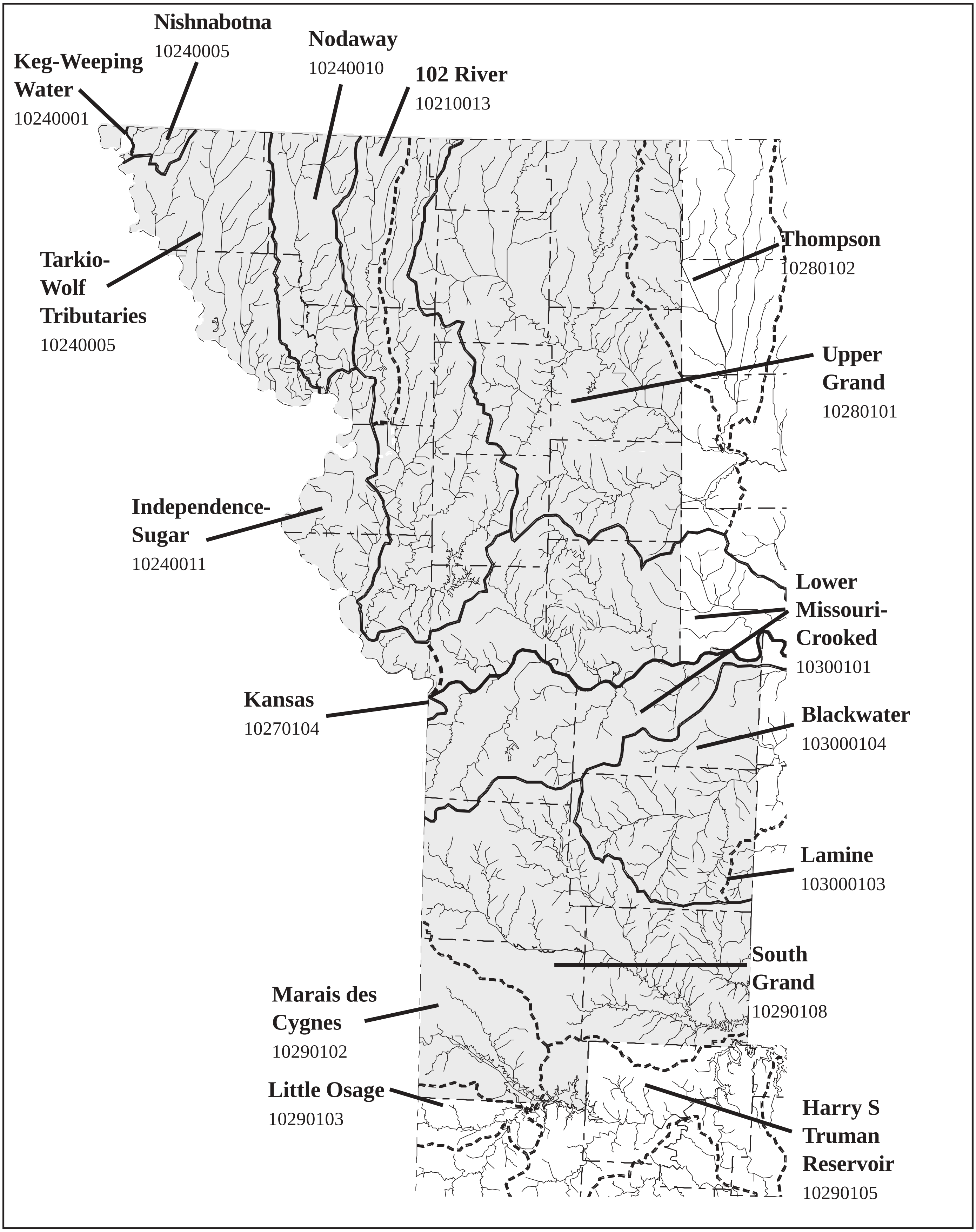

Figure 13. Watershed drainage patterns for northwest Missouri.

annual precipitation averages 34 inches per year in the northwest corner, lowest in the state, to 39 inches per year in the southeast corner of Ray County, to 42 inches in southern Bates County (figure 7). The average annual lake evaporation rate is approximately 40-44 inches in the northwest region (figure 15). This combination of moderate precipitation amounts, relatively high evaporation, deep soils, and relatively shorter growing seasons than other parts of the state, contribute to the northwestern region's water supply vulnerability to drought. In the last century, the northwestern region has experienced approximately 24 mild to moderate droughts, 15 moderate to severe droughts and 2 severe to extreme droughts (Drew and Chen, 1997). Thus, over a 100-year period, there were 41 droughts of varying severity, which is quite a high average.

With the exception of the Missouri River alluvial corridor, the northwestern region lies within an area that is designated by the *Missouri Drought Response Plan* as having high drought susceptibility. Within this area, surface

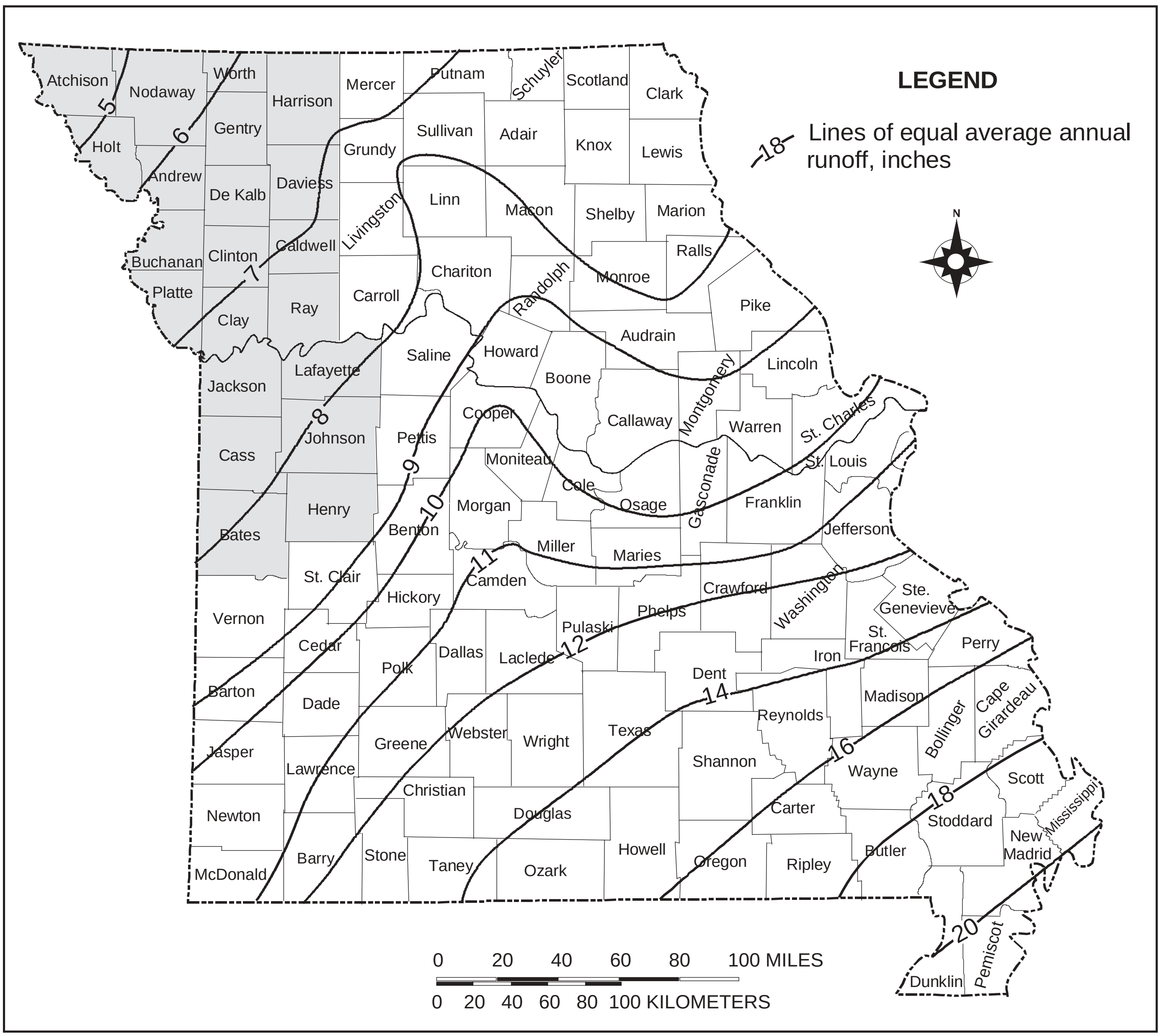

Figure 14. Average annual runoff in Missouri. Source: Skelton, 1971.

water sources usually become inadequate during extended droughts and groundwater resources are severely limited. Public, domestic, and industrial water sources are typically from reservoirs, river intakes and river alluvium wells. Virtually all of the rural private domestic water needs within the region are supplied by shallow wells.

Agriculture uses are usually some of the first to feel the effects of drought since row crops are extensive in this area of the state, and irrigation is not extensive due to economic feasibility. Where irrigation is used, in Atchison, Nodaway, Holt and Andrew counties, the withdrawals for crops can adversely affect other uses. Whether supplied by surface or groundwater sources, drought combined with agricultural demands can quickly overtax the limited water supplies. Farm ponds, which can be and usually are severely impacted by prolonged, severe droughts, typically supply livestock water needs. Livestock grazing is not as vulnerable as row crops to short duration droughts. This is especially true during certain phases of the crop

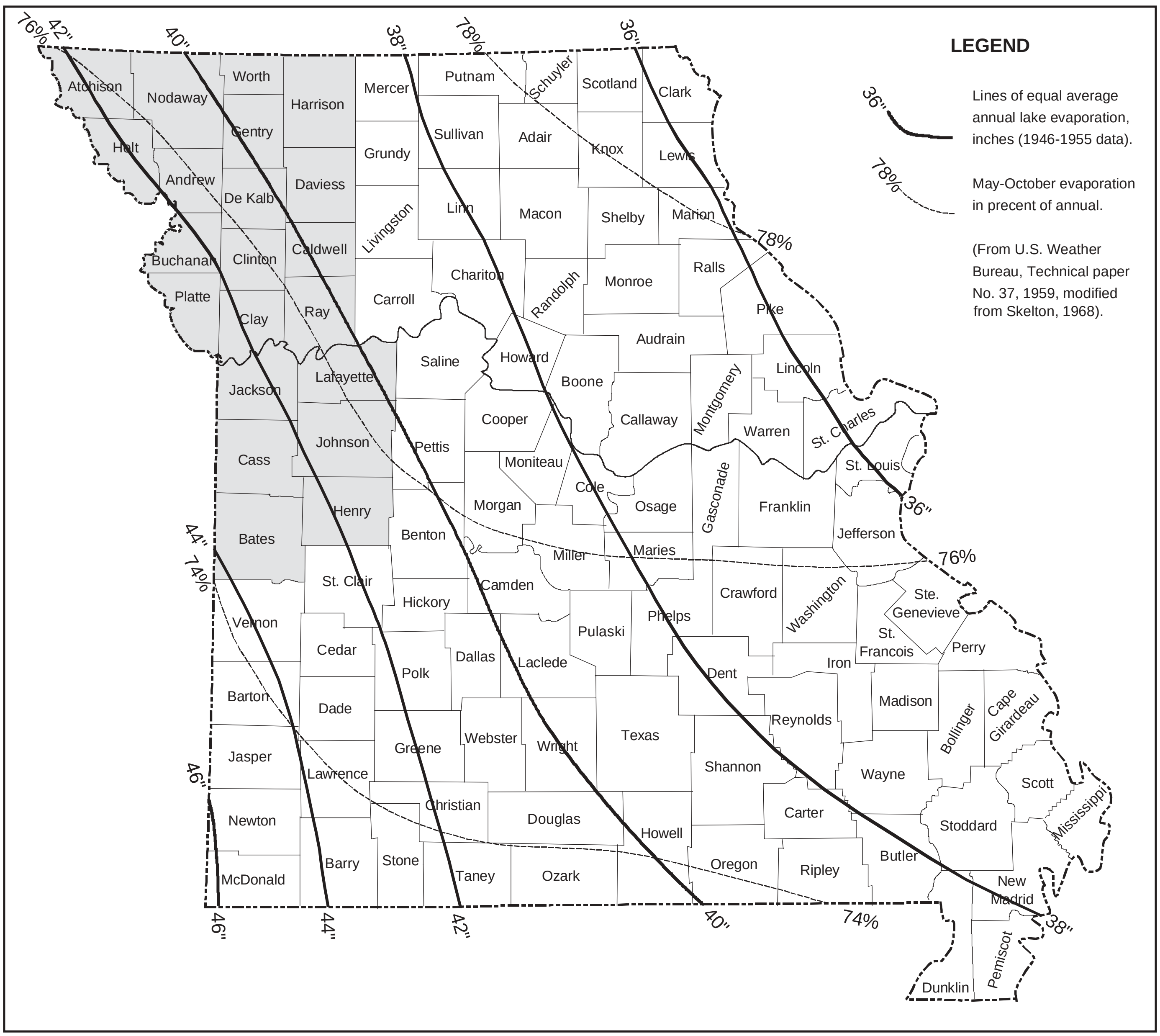

Figure 15. Estimated annual lake evaporation in Missouri.

growth. Approximately three-fourths of the demand for livestock water is met by surface water supplies, while groundwater resources supply over 90 percent of the water used in irrigation (DuCharme and Miller, 1996).

Commercial barge navigation on the Missouri River requires adequate river water levels for the tows and their barges to operate. Severe drought conditions affecting flows of the Missouri River can hamper or completely stop barge traffic.

One of the largest uses of water in this region is for power generation. All types of electrical power generating plants "use" massive quantities of water for cooling or steam generation or falling water to power turbine wheels. Power suppliers are especially susceptible to droughts that occur in the summer or the winter, as these are the two peak electrical demand seasons. Again, low river stages can curtail operations, if water intake pipes cannot draw fully from the river.

Not only does drought adversely impact domestic, agricultural, and industrial water supplies and needs, it also hurts fish and wildlife. Seasonal and cyclical variation in precipitation amounts is natural. However, as drought conditions worsen, habitat can deteriorate to critical levels. This scenario is even more damaging in an already over-burdened system where the limited water resources are needed for other uses.

There is a current transition from privately supplied water to public water suppliers. By pooling financial resources into multi-user public supplies, the resultant systems are less prone to drought impacts. Even so, small systems are still more susceptible to drought impacts than large systems and even large systems are not immune.

In the rural areas of the region, many small communities operate their own city water works. Often, in periods of drought, these communities are especially hard hit. This is due to undersized and poorly maintained reservoirs and water wells and inefficient, aged, leaking pipes and infrastructure.

The Missouri River alluvium provides most of the drinking water for metropolitan Kansas City and St. Joseph. The U.S. Army Corps of Engineers (COE) controls much of flow of the Missouri River. A combination of events have arisen in recent years with the COE invoking certain river management practices and some upstream states have taken steps to withhold water from the lower portion of the river, effectively denying Missouri water that it needs.

Three counties in the region, Jackson, Cass and Bates, abut the Kansas state border. This is significant in two aspects. Kansas, unlike Missouri, practices prior appropriation water law doctrine. In the event of drought, Kansas may prevent surface water flows from leaving that state and entering Missouri. Obviously, this is a detriment to those three Missouri counties.

Sources:

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Lack of Model Contracts for Public Water Supply Systems' Cooperation

Problem:

Public water suppliers frequently enter into contractual agreements with other public water suppliers. Standard contracts have not been devised to help streamline this process, and often poorly written contracts between water suppliers contain language that is disadvantageous to one or both parties.

Discussion:

When communities throughout Missouri began developing public water supply systems to provide safe drinking water to their residents, rural water districts had not yet been created and the distance between towns made interconnection an unrealistic alternative. Therefore, most western Missouri municipalities, even those with populations of only a few hundred people, developed community public water supplies. Depending on their locations and potential water sources, they constructed reservoirs, installed river intakes, or drilled wells to provide raw water, and built treatment plants to supply finished water.

Construction of many water supplies began before or during the Depression of the 1930s, when labor costs were relatively low. Rising costs of new supplies and the need to replace outdated reservoirs and treatment plants have made it difficult for many smaller northwestern Missouri communities to continue to supply water to their residents. They can no longer provide sufficient financial support for their water supplies, making interconnection with another supply desirable. The legal aspects of interconnection can, however, create difficulties for those involved. In the past, contracts between water suppliers have included terms unfavorable to one or both parties. Standardized contracts, which would include terms favorable to all, have not been developed for agreements between water

suppliers. Without standard contracts, struggling public water suppliers in northwestern Missouri may be reluctant to pursue interconnection with other supplies, despite the potential benefit.

Some Small Water Districts May Not Adequately Supply Water

Problem:

Small public drinking water suppliers sometimes have difficulty supplying adequate water quality and quantity to their customers.

Discussion:

Small public water supply systems sometimes face water supply/water quality problems they are inadequately prepared to solve. In many cases, existing rate structures do not cover the costs of capital improvements and maintenance, and managers of small water systems often focus upon daily operations rather than financial issues. Consequently, many small public systems are not able to maintain adequate cash reserves to repair, upgrade, or construct new facilities. Combining systems is a solution, but many districts are reluctant to combine.

Many of northwestern Missouri's public water suppliers serve small communities. Over 50 percent of the public water supply systems found within the region have service populations of 1,000 or fewer people. Many small municipal systems have been in operation for a half century or more; the average age of municipal systems serving fewer than 1,000 people or less is 39 years, and 17 percent of them are more than 50 years old (Missouri Department of Natural Resources, 2000). These older systems require replacement or upgrades more and more frequently.

An adequate and fair rate structure is essential to the operation of any utility. This allows the utility to generate funds for proper management, operation and maintenance, and amortization of any outstanding loans. However, in many small water supply systems, there is a lack of earnings to accomplish these responsibilities, resulting in substandard service and poor water quality (USEPA, 1991).

There are examples of communities in northwestern Missouri not setting the appropriate rate structures. This situation may arise for several reasons. The managers of a small public water supply system may be so occupied with facility operations that they may have little time to address financial issues. Passing capital costs on to the service population is sometimes a concern and many water systems wait too long before increasing user service charges for improvements because they fear adverse customer reaction (USEPA, 1991). Operational costs, such as electricity, chemicals, payroll and training, must be accounted for in the rate structure as well.

In recent years, in addition to the Community Development Block Grant (CDBG) Program of the Missouri Department of Economic Development (DED), there now is a Missouri Water and Wastewater Review Committee. This includes the CDGB Program, DED; the Rural Development Program of the U.S. Department of Agriculture, State Office (Columbia), and the Department of Natural Resources Financial Services Office (Revolving Loan Funds). This body meets twice each month to discuss criteria for making loans and grants to local governments, and make recommendations and suggestions to local governments, relative to rate structures, regionalization of water supplies, etc.

In the past, in some instances, Community Development Block Grants have been used to provide an alternative to rate restructuring to make capital improvements. However, some communities do not have the economic foundation to raise the needed capital improvements, and they let their system degrade to the point where it becomes a human health and economic crisis.

Substandard service can manifest itself in many ways. In some cases, a utility may not be able to provide new water supplies and additional infrastructure needed to support growth in the service area. Aging facilities and infrastructure may require upgrades or replacement, and a utility may lack the necessary funds. Water quality problems may call for new, improved treatment measures that a utility may be unable to provide.

Historically, every community has had its own water supply and sewage treatment plant. These communities usually want to be in control of their respective systems. In part, this is due to economic circumstances since the revenue from the water district sometimes is a major source of revenue for the community. They fear losing this revenue were they to combine with other districts. Pride and a sense of independence can also be factors in a community wanting to maintain their own water supply. They fear that if someone else is in control of the supply, their customers will pay more for water. However, they are often not charging enough for the water in the first place. There is sometimes a lack of infrastructure that would enable the systems to combine. Also, there are instances of outdated contracts which forbid a water system from selling or purchasing water from someone other than the supplier stipulated in the contract.

Sources:

Missouri Department of Natural Resources, Division of Environmental Quality, 204 p., 2000, ***Inventory of Missouri public water systems, 2000.***

United States Environmental Protection Agency (USEPA), 1991, ***Manual of small public water supply systems,*** 193 p.

Aging Infrastructure of Public Water Supply Systems

Problem:

The basic equipment, structures and installations public water suppliers use to provide services can become less efficient or break with age and become undersized with increasing demand. It is difficult for many communities to find the money to adequately update their systems. Since much of the population of northwestern Missouri is served by public water supplies, any problems associated with aging water supply infrastructure will need to be addressed.

Discussion:

The National Water Use Information Program of the USGS estimated in 1995 that 87 percent of the population of northwestern Missouri was served by public water supplies. While the ages of municipal water supply systems and public water supply districts in northwestern Missouri range between 9 and 126 years, 45 percent of them are between 31 and 50 years old, and 15 percent of them are 71 years old or more.

The problems caused by aging water supply infrastructures are many. Aging water lines made of materials inferior to those allowed by current technology become fractured and begin to leak. Leakage, also called "transmission loss," reduces system efficiency and can have a negative impact on the system's revenue generation. This, in turn, may make it more difficult for the water supply system to finance much needed improvements in the future. A more common problem is the rupture of old water lines, which means that customers are without water until the lines are fixed, and there can be significant disturbance above-ground since workers have to tear up the surface (often a road) to get to the pipes (Ryser, 2001).

Aging water supply infrastructures may also impact water quality. Outward leaking pipes also can leak inward if there is a sudden loss of pressure, allowing the system to become contaminated. In addition, service connections may have lead joints, which may leach lead into drinking water. In the human body, accumulations of lead as well as prolonged exposure to even very small amounts of lead can result in serious health problems. Older systems may also have "dead-end" lines in which water may become stagnant and undrinkable. Some rural water districts laid water lines with an older form of PVC piping, which now leaches vinyl chloride (a known human carcinogen) into the water when it is at a dead end for a while (Timmons, 2001).

Quite often, lines and facilities that were adequate when they were first constructed, are undersized when it comes to present service requirements. With age, systems may no longer be able to convey the amount of water that system users need. Present household, industrial

and public uses (such as firefighting and drought response) may be limited. Without viable alternatives, future development may also be restricted as potential users are discouraged from locating their facilities in a service region unable to support their needs.

Kansas City is an example of the problems caused by aging infrastructure. It is an old system, functioning since 1875. In 1996, they passed a $150 million bond to maintain and upgrade their drinking water supply system. This bond will help replace about 10 percent of their mains by 2007. However, at a cost of $400,000 to $500,000 per mile, they won't be able to fully replace their system as it ages, thus the age of the entire system is increasing. In addition, they have 600-700 main breaks per year, which costs a lot of money and inconveniences people (Ryser, 2001).

Sources:

Ryser, E., Manager of Systems Engineering Division, Kansas City Water Department. Personal communication, February, 2001.

Timmons, T., Missouri Department of Natural Resources, Water Protection and Soil Conservation Division, Public Drinking Water Program. Personal communication, February, 2001.

AGRICULTURAL WATER USE

Improper Land Application of Animal Manure

Problem:

Improper land application of animal manure can impair water quality. Confined animal feeding operations (CAFOs) have caused serious water quality problems in northwest Missouri and may also have affected water quantity.

Discussion:

If animal wastes are applied to cropland or pasture at rates greater than can be used by growing plants (the agronomic rate), runoff carries excess nutrients into surface waters. Excessive nutrient concentrations that migrate from the land and enter waterbodies may lead to increased algal growth, toxic blue-green algae blooms, magnified diurnal oxygen cycles that negatively impact aquatic species, and reduced aquatic invertebrate species diversity. Increased bacterial loads can cause or promote fish and wildlife diseases and make the water unsafe for human recreational use. Over time, these water quality problems can cause the decline of sensitive fish species such as the Topeka shiner.

Large volumes of fresh water are required for some types of CAFO operations. Construction of impoundments that supply livestock water can reduce base flow in headwater streams. This base flow is most critical during dry periods. Aquifers may also be locally impacted by CAFOs that rely on groundwater for their water supply.

There are currently 38 large, permitted CAFOs in the northwest Missouri region – nine in Bates County, 11 in Henry County, and 18 in Johnson County. These operations house a total of 69,950 animal units (Bates 13,099; Henry 5,851; and Johnson 51,000) (Tackett, 1999). Twenty pollution incidents were attributed to livestock manure in the Kansas City Region from 1990 to 1999. Hog manure caused 16 of the problems, cattle manure, three, and poultry manure, one.

Two streams with chronic problems are Camp Branch and Campbell Branch in Bates County. One producer near Camp Branch was documented polluting on at least three different occasions over a seven-year period (1992-1998). Six of the 20 documented pollution incidents caused by CAFOs have occurred in these two small streams.

Sources:

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Atrazine in Water

Problem:

Elevated concentrations of atrazine in drinking water may pose a risk to human health. The presence of atrazine in both surface and groundwater may increase the cost to public water suppliers for treating drinking water. Herbicides such as atrazine may have negative impacts on the aquatic communities of surface waters in Northwest Missouri.

Discussion:

The herbicide atrazine was first introduced in 1959. Since that time, because of its effectiveness, atrazine has become the number one herbicide for use in corn production. Atrazine can enter surface waters through runoff from crop fields located in the watershed. Atrazine breaks down slower in water than on land, with a half-life in northern lakes (including northwestern Missouri) of 8-16 months. Since atrazine does not adsorb to soil particles and does not decay quickly, it can be transported to groundwater.

The nonpoint-source runoff of herbicides into surface waters used as drinking water supplies is a concern to human health. It is also believed to be carcinogenic (USEPA, 2000). Many public water suppliers in Northwestern Missouri use surface water as their source of raw water. Elevated concentrations of atrazine are very common in this raw water during the spring and summer following the application of herbicides to row crops. The U.S. Environmental Protection Agency (EPA) established an MCL (maximum contaminant level) of 3 ppb for atrazine in drinking water in 1993. In 1994, three water supplies in Northwest Missouri were out of compliance due to atrazine concentrations.

To meet EPA guidelines, public water suppliers must remove the atrazine, which has increased the cost of treating drinking water. Powdered activated charcoal (PAC) is the most common treatment used. At least four public water supplies in Northwestern Missouri (Dearborn, Hamilton, Jamesport and Cameron) have spent funds to remove atrazine from drinking water.

Proposed ambient aquatic life water quality criteria for atrazine have been developed by EPA. Freshwater aquatic animals should not be negatively affected if the four-day average concentration of atrazine does not exceed 12 ppb more than once every three years on the average, and if the one-hour average concentration does not exceed 330 ppb more than once every three years on the average. For the protection of freshwater aquatic plants, and indirectly for aquatic animals, the four-day average concentration of atrazine should not exceed 49 ppb (USEPA, 1997).

Extensive research has been conducted on the impacts of atrazine to aquatic communities (USEPA, 1997). Significant reductions of both species richness and total abundance of insects was observed at 20 ppb in experimental ponds in Kansas (deNoyelles et. al,. 1989). The lowest concentration of atrazine that has resulted in negative effects on abundance of aquatic plants and animals occurred at 15-20 ppb. Concentrations above 50 ppb cause more severe reductions in productivity, plant biomass and community structure as well as indirect effects on herbivorous invertebrates and fish. (USEPA, 1997). Atrazine levels in surface waters in northwestern Missouri have exceeded levels found to have adverse impacts on the aquatic community.

Sources:

deNoyelles, F., W.D. Kettle, C.H. Fromm, M.F. Moffett and S.L. Dewy, 1989, "Use of experimental ponds to assess the effects of a pesticide on the aquatic environment," in:

Using mesocosms to assess the aquatic ecological risk of pesticides: theory and practice, Voshell, J.R. (Ed), Miscellaneous Publications Number 75, Entomological Society of America, Lanham, Maryland.

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Smith, M. and M. Sobba, 1997, ***Goodwater ag day research and reports, July 18, 1997,*** Missouri MSEA Water Quality Project, Outreach and Extension, University of Missouri-Columbia, 22 p.

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U.S. Environmental Protection Agency (USEPA), 2000, Re-evaluation by the FQPA Safety Factor Committee, available at: www.epa.gov/pesticides/reregistration/atrazine/fqpa_rpt.pdf

United States Geological Survey (USGS), 1994, ***Occurrence of herbicides, nitrites, nitrates, and selected trace elements in groundwater from northwestern and northeastern Missouri, July, 1991 and 1992,*** OFR 94-332.

INDUSTRIAL WATER USE

Mine Runoff

Problem:

Erosion, sedimentation, acid mine drainage, high sulfate concentrations, and iron manganese deposits, are all problems associated with strip mining and its runoff. Currently all mining operations are required to reclaim mined lands, which should help to sustain and improve water quality. Many of the older strip mine areas in western Missouri are in need of reclamation to reduce acid mine runoff to streams.

Discussion:

Marais de Cygnes River, Miami Creek, South Grand River, and Tabo Creek have all been negatively impacted by run off from abandoned and active strip mining operations. Walnut Creek, Mulberry Creek, Park Branch, New Home Creek, and Miami Creek are tributaries to the Marais de Cygnes River that have been negatively impacted by runoff from coal strip mines. Walnut Creek is the most impacted of the streams listed. As of 1992, nine miles of Mulberry Creek and four miles of Walnut Creek were mineralized by coal mine drainage, but no streams were believed to be acidified (Dent et al., 1997). Tabo Creek is the most heavily impacted stream, associated with acid mine drainage, in the South Grand River watershed. These all are tributaries to Harry S Truman Reservoir.

Table 4 shows streams affected by mine drainage from the list of 1998 Impaired Waters provided by EPA and the Missouri Department of Natural Resources' (303(d)). Within the two watersheds (Marais de Cygnes and South Grand) represented in Table 4, problems with mine drainage make up 33 percent of the listings for both watersheds and 64 percent of the listings for the South Grand River watershed, with 100 percent of the listed waterbodies affected in the Tabo Creek watershed being related to mining runoff.

Stream	County	Parameter of Concern	Source of Impairment
Trib. to Baker Creek	Henry	PH	Grey Coal Area
Big Otter Creek	Henry	PH	Otter Creek Coal Area
Trib. to Big Otter Creek	Henry	PH	Otter Creek Coal Area
Honey Creek	Henry	Sulfate	Reliant Coal Area
East Fork Tabo Creek	Henry	PH	Triple Coal Area
Middle Fork Tabo Creek	Henry	Sulfate and pH	New Castle Coal Area
West Fork Tabo Creek	Henry	Sulfate	Spangler Coal Area
Mulberry Creek	Bates	Sulfate	Mulberry Creek Coal Area

Table 4. Listing of 1998 impaired water within Bates and Henry counties, Missouri. Source: EPA, 1998.

Runoff from mined areas has been responsible for eight fish kills (Henry County) totaling over 116,000 fish (MDC, 1968-1999). The majority of these kills occurred in the 1960s (2), 1970s (5), and 1980s (1). Fish kills have been greatly diminished, since the mined lands have been reclaimed.

Sources:

Dent, R., D. Fantz, W. Heatherly, and P. Yasger, 1997, ***West osage river inventory and management plan.*** Missouri Department of Conservation, Jefferson City, Missouri.

Environmental Protection Agency (EPA) 1998. Missouri 1998 impaired waters (303 (d)).

Missouri Department of Natural Resources [Online]. South Grand Available at www.epa.gov/iwi/303d/10290108_303d.html, Blackwater Available at www.epa.gov/iwi/303d//1030104_303d.html, and Lower Marais de Cygnes Available at www.epa.gov/iwi/303d//10290102_303d.html

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ENVIRONMENTAL WATER USE

Channelization and Associated Sedimentation

Problem:

Stream channel incision is widespread in northwestern Missouri. This is the deepening and associated widening of stream channels resulting after channelization and increased runoff as a result of land use practices.

Discussion:

Channelization was a widespread government-supported and condoned stream management practice from 1908 to the 1970s. The intent was to prevent streams from meandering, thereby assuring farmers their fields would not slough off into the stream. Stream channelization has been common in most watersheds in northwestern Missouri. In downstream reaches, the channel capacity decreases, resulting in more flooding and sediment deposition.

Channelized reaches of streams are less productive to fish and wildlife (due to loss of fish habitat, spawning habitat and wetlands) and less diverse than unchannelized reaches. A study

on the Platte River in Northwestern Missouri found an 85 percent reduction of fish biomass from a channelized to an unchannelized reach. The study also found a 77 percent reduction in the number of harvestable size (>10 inches) fish and a 90 percent reduction in the pounds of harvestable size fish from channelized to unchannelized reaches (Michaelson, 1971).

In the Platte River watershed over 250 stream miles have been channelized. This represents about a 20 percent loss reduction of stream mileage within the basin (Bayless and Travnichek, 1997). Ninety-four of the original 105 miles of the mainstem Nodaway River within Missouri have been channelized, and over 75 percent of the original stream mileage within the basin has been altered by channelization (Horton and Bayless, 1998).

The Blackwater River watershed in southeastern Johnson County has been channelized. Forty-seven of the original 103 miles (46 percent) of mainstem North and South Fork Blackwater Rivers, the mainstem Blackwater River, and Davis Creek have been channelized (Missouri Department of Natural Resources, 1986).

The pilot channels in the Blackwater River watershed created problems that continue today. United States Geological Survey (USGS) records show that the stream bottom at the Blue Lick gage station has aggraded six feet from 1922 to 1975. During this same period, the upper reaches of Davis Creek and the Blackwater River have degraded 30 feet or more. As a result, the fall of the stream has been reduced from the original 85 feet to the present 49 feet in a distance of 50 miles (a reduction of 0.7 ft./mi.) (USDA, 1977).

Downstream flooding attributable to channel straightening is responsible for major economic losses to agriculture, roads, bridges, and buildings (USDA, 1977). An estimate of projected economic losses caused by flooding for the Blackwater River watershed for the year 2000 was $2,544,850 (USDA, 1977).

Seventy of the original 159 mainstem miles (44 percent) of the South Grand River (Bates County) have been channelized. An additional 62 miles (39 percent) have been impounded by Harry S Truman Reservoir, for a combined alteration and loss of 132 miles (83 percent) of original stream channel.

The largest channelization project in the northwestern region involved the Marais des Cygnes River. In the early 1900s, this river was considered the most sinuous in Missouri (Atkenson, 1918).

The lower 44 miles were channelized to create the 23-mile long Bates County Drainage Ditch. Currently, head cutting has caused numerous sections to become over 60 feet deep and 200 feet wide. The Marais des Cygnes River is one of the most extensively channelized rivers in western Missouri (Dent, R. et al., 1997).

In addition to construction of the Bates County Drainage Ditch, 12 miles of tributary streams were subject to “lateral straightening.” During this same period, the lower 4.5 miles of Miami Creek (Bates County) were channelized, creating the 5.7-mile Miami Drainage Ditch. This project relocated the stream’s confluence with the Marais des Cygnes 9 miles downstream from the original site, increased stream length by 1.4 miles, and increased overall length by three percent. This channelization has increased sedimentation in many portions of the channel (Dent, R., et al., 1997).

The latter two channelization projects, in addition to being hydrologically and biologically unsound, were also poorly engineered, as indicated by the many portions of the ditches that did not “take.” For example, only 1.9 miles of the 5.7-mile Miami Drainage Ditch are part of that stream’s permanent flow channel. In addition, the upper 3.1 miles of the Bates County Drainage Ditch have never become the permanent flow channel of the Marais des Cygnes River. Permanent flow in the Marais des Cygnes River above the confluence of Miami Creek occurs only during flood events. The old river channel is rapidly filling with sediment (Dent, R., et al., 1997).

Channelization has caused the Marais des Cygnes River to virtually cut a new river valley. During periods of low flow, the river tends to meander through this wide valley. Head-cutting has reached bedrock in many areas. Therefore, lateral instability will continue and result in additional erosion and sedimentation downstream. Sedimentation is already extensive in the upper reaches of Truman Lake. Erosion and instability will continue until the stream reaches gradient equilibrium by increasing its length by

meandering through a wide valley. This process could take centuries (Dent, R., et al., 1997).

Sources:

Atkenson, W.O., 1918, ***History of Bates county, Missouri,*** Historical Publishing Company, Topeka, Kansas, pp. 292-297.

Bayless, M. and V. Travnichek, 1997, ***Platte river basin inventory and management plan,*** Missouri Department of Conservation, Jefferson City, Missouri.

Dent, R., D. Fantz, W. Heatherly, and P. Yasger, 1997, ***West Osage river inventory and management plan,*** Missouri Department of Conservation, Jefferson City, Missouri.

Horton, R. and M. Bayless, 1998, ***Nodaway river basin inventory and management plan,*** Missouri Department of Conservation, Jefferson City, Missouri.

Michaelson, S.M., 1971, ***Fish population in channelized and unchannelized sections of the Platte river, Missouri,*** Presentation at the 33rd Annual Midwest Fish and Wildlife Conference (Missouri Department of Conservation internal document).

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Erosion and Sedimentation

Problem:

By the very nature of the topography and geology of the region, both in the glaciated area north of the Missouri River, and Cherokee Prairies soils of the Osage Plains region of western Missouri, sedimentation is a major natural characteristic of all streams. One of the most widespread water quality and stream habitat issues in these areas is excessive deposition of soil in streams and lakes from human-related activities. Soil erosion and sedimentation from row cropping, grazing practices, construction sites, and the change of water flow rates caused by urbanization have impacted stream habitat and aquatic life in many of the watersheds in the region.

Discussion:

Soil erosion is a natural physical feature of the region due to the area's precipitation amounts, precipitation patterns, slope, soil type, soil thickness, topographic, and geologic characteristics. Unlike the streams of the Ozarks, for example, the prairie type streams in northwestern Missouri have naturally occurring mud bottoms. Streams within the Grand River basin are typically turbid. Historical accounts indicate many basin streams have always been muddy (Pitchford and Kerns, 2001). The physical characteristics of most of this region are a result of Pleistocene glaciers. These glaciers left behind deposits of extremely variable thickness, in places nearly 400 feet thick (Brookshire, 1997). These are unconsolidated sediments on top of Pennsylvanian- and Mississippian-age bedrock. This glacial till has, over the ages, been dissected by runoff-caused erosion. The drainage pattern of the region consists of semi-parallel streams that trend from the north to the south, draining to the Missouri River (Vandike, 1995). "The combination of channel alterations and inadequate corridors has resulted in tall streambanks that are rapidly eroding. Except in the uppermost portions of the watershed, nearly all streambank erosion problems are too severe for biotechnical measures to be practical" (Pitchford and Kerns, 2001). This region, the Dissected Till Plains, is characterized by glacial till that has very low permeability, and therefore, infiltration is low and runoff rapid. This low permeability and the lack of groundwater inflow into streams make for very low base stream flows during dry weather (Vandike, 1995, and Miller and Vandike, 1997).

The area immediately south and south east of Kansas City is called the Osage Plains. Their

soil characteristics are of glacial till covering Mississippian-age bedrock (Miller and Vandike, 1997, and Vandike, 1995). Some loess was deposited in the Missouri River alluvial valley (Miller and Vandike, 1997) and south of the Missouri River in the Cherokee Prairies soils subregion of the Osage Plains (Missouri Department of Natural Resources, 1986). The silt has low permeability in many areas. The till is exposed by erosion through the loess as watercourses erode the layers of soil. It is not so much the glacial till as it is the loess that causes the sediment problem. This is what leads to high loads of suspended sediment in streams, and muddy bottoms.

Human activities, land development and agriculture have increased the naturally occurring rates and locations of erosion and sedimentation. The Osage and the Dissected Till Plains region, are extensively row-cropped, with the result being that the loess and glacial till are easily eroded, especially on steeper slopes. This combination leads to high suspended sediment loads in many rivers and streams (Vandike, 1995). Some factors that contribute to increased sedimentation are short-term, short-duration events, while others may affect water quality and quantity over long periods of time (Brookshire, 1997). Heavy rains and flash floods are examples of short-term/duration events that increase sedimentation while major land use changes such as converting a forested area to row crops or suburbs can be cited as long-term events. In areas adjacent to suburban developments, excessive sedimentation can be even more pronounced.

Soil erosion increases water turbidity, which can have negative impacts on aquatic life. Many of the aquatic life species have developed a certain tolerance to muddy water. However, when sedimentation is excessive, it can adversely effect even the highly evolved and specialized sediment-tolerant species. While a certain degree of sedimentation is necessary and can create spawning habitat and rearing areas, excessive sediment can fill pools and shallows, making them less desirable or even unsuitable for aquatic life. Additionally, this can cause some aquatic species to be more susceptible to terrestrial species predation. Sediment also fills lakes and ponds, which also reduces this type of habitat for certain aquatic species (see "Aging Water Impoundments" topic write-up).

Excessive sedimentation and excessive turbidity can reduce the individual species number and species diversity of naturally occurring and adapted aquatic invertebrates and vertebrates that require deep pools or shallows. Turbidity and siltation can also result in the reduction or loss of fish populations. This is usually not the result of direct mortality, but rather caused by sublethal effects like reduced feeding and growth, respiratory impairment, reduced tolerance to disease, stress, and reduced reproductive success brought on by over-concentration.

The deposition of excessive sediment fills in stream pools. As these pools lose the ability to hold water, adjacent stream banks are subjected to increased scour and bank erosion is possible. Excessive sedimentation in stream channels can increase the likelihood of localized flooding because the channel has less capacity to carry floodwater. Deep pools are critical refuges to certain species during low flow periods especially in summer and winter. Loss of these deeper water habitats can concentrate the animals in marginally suitable habitats where competition among and between species increases. This also increases the susceptibility to stress, disease and predation. Water quality problems in pools may also become magnified, as less deep-water habitat is available.

SPECIFIC EXAMPLES:

Within the northwest region, five miles of Dog Creek in Daviess County, and 0.2 mile of Long Creek in Caldwell County, are listed as 1998 category 1 Clean Water Act Section 303(d) waters due to sediment from point sources, specifically quarry operations. Ten counties are listed as category 2 CWA Section 303(d) streams because they are sediment impaired from nonpoint agricultural sources. The counties and stream miles affected in category 2 include: Johnson County-54 miles, Harrison County-18 miles, Daviess County-17 miles, Ray County-14 miles, DeKalb County-47.5 miles, Gentry County-50 miles, Nodaway County-14.5 miles, Bates County-18 miles, Andrew County-11 miles and Atchison County-17.5 miles. The Marais des Cygnes River has been proposed for inclu-

sion on the 2002 Section 303(d) list for sediment pollution caused by agricultural erosion.

Lakes on Reed Conservation Area in Kansas City have received large amounts of sediment from construction sites in the watershed(s). This sediment has reduced the depth and life span of these lakes.

Gross erosion amounts in the Blackwater River watershed are estimated to average 12.7 tons per acre annually. Of this, an estimated 3.3 million tons arrives in suspension where the Blackwater River enters the Lamine - Missouri River. Erosion and sediment yields have increased as woodlands on private land have been converted to cropland (USDA 1977).

Sedimentation is a problem in the upper reaches of Truman Reservoir. Both the South Grand River and the Marais des Cygnes River, tributaries of the Osage River, flow into Truman Reservoir.

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Levee Construction and Flood Plain Management

Problem:

Levees are relied upon to hold back water during floods but no coordinated system of oversight exists to ensure their ability to function as intended.

Discussion:

As part of the Pick-Sloan Plan for reducing flood damages on the Lower Missouri River (and for augmenting low flows on the Missouri for the benefit of water supplies, power generation, irrigation, and navigation), Congress passed legislation in 1944 that called for the construction of large dams and reservoirs in the Upper Missouri Basin, and for the building of levees along the mainstem of the lower river (Federal Flood Control Act of 1944.)

In addition to the construction plan for dams and levees, there is an operating plan for the river, governed by the Master Water Control Manual, under which Annual Operating Plans (AOPs) are adopted by the Northwestern Division of the Corps. It is the AOPs that govern the manipulation of the stages of the Missouri River. Despite the large capacity for flood control inherent in a system of six major dams and their reservoirs, floods and droughts still occur in the Missouri River Basin. Most of the State of Missouri (and the entire northwestern region) is situated within the Lower Missouri River Basin.

Following the flood of 1993, which affected the Upper Mississippi Basin and the Missouri Basin, a number of agencies prepared reports on the flooding, identifying factors that reduced or aggravated flood damages. They made recommendations, which would help to reduce future flood damages.

An analysis of the four major reports prepared after the 1993 flooding found, among other things, that "more state involvement in the whole [levee] topic area was universally recommended, especially in oversight and permits" (Gaffney, 1996). All four of those major reports made recommendations about levees, highlighting the importance of levees in reducing (or aggravating) flood damages, and in raising flood stages. Included were discussions of setbacks for levees, giving rivers more lateral space to spread out during high flows.

In particular, *The Report and Recommendations of the Governor's Task Force on Flood Plain Management,* 1994, called for a levee permit system, which bordering states Kansas and Illinois already have. The purpose is for developing design criteria, for consideration of setbacks from the riverbank, for consideration of other uses of flood plain land, and for maximum use of the Wetland Reserve Program and the Conservation Reserve Program to reduce flood damages (Gaffney, 1996).

The flood of 1993 on the Missouri River was a very large flood, the magnitude of which varied with the reach of the river. In most locations, it was considered to have been a "more than one hundred-year flood," that is, one which would be expected to recur less frequently than once every century. Following the flood of 1993, there was the flood of 1995. Statistically, it is possible to have "hundred-year floods" back-to-back, or in rapid succession.

The 1995 flooding did not cause the devastation of the 1993 flooding because a number of flood plain recommendations had been carried out in the interim. One of the measures taken was the removal of many flood prone dwellings from the flood hazard areas along the river. These "buy-outs" were made possible by creative financing, using a number of federal and non-federal revenue sources, catalyzed by the Department of Natural Resources, Water Resources Program personnel during the flood recovery period, 1993-1994.

Some of the damages from the 1993 flooding were caused by levee failures. Some were design failures (such as overtopping), but some were structural failures. When a levee "blows," that is, when a levee gives way under the pressure of floodwater, the force of the flow of water passing through the crevasse often causes deep scouring of the land, and subsequent deposition of sediment below the scour holes.

A later study showed that a forested riparian corridor between the river and any levee had a marked effect on the force of floodwaters against a levee. A width of 300 feet of woody

vegetation was shown to be most effective in protecting a levee against failure, even in high-energy areas of the Missouri River (Dwyer, 1997).

Levees also raise flood heights (stages) by constraining the lateral spreading of floodwaters. Like the nozzle of a garden hose, the narrowing of a river at high flows by the placement of levees or floodwalls has two principal effects: the raising of flood stages and the increase of current velocity. Both of these effects cause damages to property along the river's reach.

Despite the severity of damages attributed to levee failures, levee setback and other recommendations made by the post-flood reports have not had the public impetus of "buy-outs" and other post-flood measures. The reports' recommendations regarding levees have not been acted upon.

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Loss of Sensitive Aquatic Species

Problem:

Land management practices and resulting degradation of stream habitats are causing the range of sensitive aquatic species to be reduced in Northwest Missouri. This degradation is resulting in the reduction of some sensitive species of fish from entire basins in Northwest Missouri.

Discussion:

Stream habitat degradation is widespread throughout Northwest Missouri. This degradation is in part due to sedimentation and nutrient enrichment from some land management practices. The construction of Truman Reservoir has also been responsible for major stream habitat reduction in Henry and Bates counties.

The crux of the problem lies in the fact that, under state law, landowners have legal, reasonable expectations that they can use their land to their benefit to, among other things, grow crops and raise livestock. Not all landowners have the time, knowledge, incentive, money or resources to make stream habitat mitigation and restoration their number one priority. For obvious reasons, state and federal wildlife agencies also do not have the staff, resources and funding needed to purchase critical sections of land to manage it solely for sensitive aquatic species.

Several fish species found with limited range in Northwest Missouri are state or federally listed. The Topeka shiner, state and federally listed as endangered, and the trout-perch, state listed S1-critically imperiled, are found in Northwestern

Missouri streams. Four fish species, Highfin carpsucker, Mooneye, Ghost shiner, and paddlefish are state ranked based on specific levels of relative endangerment. Major threats to long-term survival of these species include riparian clearing, and nutrient enrichment of streams resulting from livestock (Pflieger, 1997; Kerns et al., 1999).

Freshwater mussels are the most endangered fauna in North America, with over 45 percent of the 300 species in jeopardy (extinct, endangered, threatened, or in decline). This holds true for Missouri mussels, particularly in areas such as the Northwestern Region where a combination of changes in physical habitat and declines of water quality have altered the free-flowing stream habitat required by freshwater mussels. Because of their unique reproductive strategy where their larval stage (glochidia) is released into the water column where it must contact, encyst upon and metamorphose on native fish, mussels are particularly susceptible to changes in water quality. Not only are the larvae extremely sensitive to water quality changes, any change in habitat that impacts a particular species of fish can impact mussel species that rely on that fish for reproduction.

Site-Specific Data:

Though once widespread across the Northwestern Region, the Topeka shiner is now restricted to the Sugar Creek basin in Daviess and Harrison counties (Gelwicks and Bruenderman, 1996; Pflieger, 1997). The trout-perch was widespread across Northwestern Missouri and is now "on the verge of disappearing from our state" (Pflieger, 1997). The loss of these species is attributed at least in part to poor agricultural land use practices, mainly row cropping on highly erodible land and the subsequent sedimentation and pollution delivered to streams. Concentrated animal feeding operations in the region now pose an additional threat to remaining populations.

Sources:

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Lack of Riparian Corridor

Problem:

Streamside clearing, combined with accelerated lateral channel erosion, has resulted in extensive stream reaches with inadequate riparian corridors. Loss of streamside vegetation results in accelerated bank erosion and floodplain scour, channel widening and shallowing, an increase in stream temperature, and loss of aquatic and riparian habitats.

Discussion:

Clearing of streamside vegetation is a serious long term problem in western Missouri that has been occurring over the last 100-150 years. Many streams have few, if any, trees on their banks. A healthy riparian corridor (a corridor of trees and other vegetation along the stream bank) should be between 50 to more than 200 feet wide, depending upon the size of the stream.

Healthy riparian corridors can improve the quality of water by removing pollutants in runoff, and increase the biological diversity and productivity of stream communities by improving instream habitat and adding to the organic food base. Streamside vegetation can intercept pollutants from both surface and shallow groundwater before they enter streams. Nutrient additions to streams increase algal production and biomass, but extreme nutrient levels can cause excessive algal productions, which increase biochemical oxygen demand. Sedimentation negatively affects fish behavior, fish reproduction, fish species diversity, and general system productivity. Streamside vegetation may impede sediment-laden runoff, causing the deposition of sediment in riparian corridors, rather than directly into the stream. Streams shaded by riparian vegetation have lower temperatures in summer than do unshaded streams. Lower summer temperatures allow higher dissolved oxygen concentration, which sustain stream biota. In Missouri, riparian forests supply a significant proportion of the energy, in the form of leaf litter, supporting food webs in streams.

Numerous stream sites within both the Platte and Nodaway River basins have been surveyed by the Missouri Department of Conservation, and most had little or no woody corridor (Bayless and Travnichek, 1997; Horton and Bayless, 1998). None of the sites surveyed had a 100 feet wide corridor, and most had less than 50 feet of woody vegetation along either streambank. Fencing of corridors was rare. Land use at over half of the sites surveyed was row crop production, often with farming up to the streambank.

Sources:

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Waste Water Treatment Facilities

Problem:

Several municipal Waste Water Treatment Facilities (WWTFs) throughout the region have been documented to be affecting the health and biota of the region's streams. Unauthorized discharges of raw and poorly treated sewage have occurred resulting in fish and other aquatic organism kills. These discharges also impair whole-body contact recreation as well as other downstream water uses.

Discussion:

Throughout the recent past (late 1960s through the present) problems with area WWTFs have occurred. Occasional discharges related with uncommonly heavy rains or outdated or malfunctioning equipment can be expected from time to time. As area populations have grown, so too has the demand on municipal sewage treatment.

Fourteen known fish kills have been caused by sewage discharges in the area, for a total of nearly 50,000 fish known killed. Another twenty incidents of unauthorized sewage entering streams were recorded over the same period (MDC, 1968-1999).

Sources:

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Pharmaceutical/Chemical Contamination of Water

Problem:

Surface waters and groundwaters of Missouri are being contaminated by various pollutants, including pharmaceuticals and personal care products (PPCPs), and other chemicals.

Discussion:

In a presentation given on April 17th, 2001, to the Missouri Water Quality Coordinating Committee, Don Wilkison of the U.S. Geological Survey (USGS) offered some preliminary findings of a current (2001) investigation on "Emerging Contaminants in Urban Watersheds," Contaminants, related to wastewater discharges, are being studied in low- and storm-flows within the Blue River watershed of the greater Kansas City area, on both sides of the Kansas-Missouri state boundary. A portion of this watershed is served by combined storm and sanitary sewers, which can, during intense rainfall events, combine and discharge untreated wastewater directly into receiving streams. Additionally, there are four sewage treatment plants that discharge treated wastewater in the basin.

Wastewater can contain trace amounts of prescription and over-the-counter drugs, detergent metabolites, and the remains of personal care products, such as cosmetics. The effects on the environment of many of these compounds are poorly understood, said Mr. Wilkison.

Many compounds would be expected to accumulate in sediments and organic matter, while other, more soluble compounds, would dissolve in water. Some components of detergents become more environmentally persistent and toxic as they break down. Some compounds are suspected endocrine-disrupting chemicals (EDCs), which can affect the glandular (hormone) systems of aquatic life (see side-bar information). Recent information on endocrine disrupters in the environment extends the scope of biological and ecological impacts of EDCs.

Among the details offered by Mr. Wilkison are the following:

- 96 percent of low-flow water samples analyzed have caffeine detected (probably from coffee and soft drinks);
- 71 percent have bisphenol A (found in plastics), suspected in endocrine disruption;
- 85 percent have triclosan (a disinfectant/antimicrobial), that may contribute to antibiotic resistance in bacteria;
- 100 percent of samples contain DEET, a component in some insect repellants; and
- 84 percent contain 5 methyl-1H-benzotriazole (an antioxidant).

Among the pharmaceuticals found in low-flow water samples are:

- over-the-counter pain killers and anti-inflammatory drugs (e.g., acetaminophen and ibuprofen);
- cotinine (the major metabolite of nicotine);
- codeine (an ingredient in some pain killers and flu medications); and
- antibiotics prescribed for urinary tract infections (e.g. trimethiprim and sulfamethoxazole).

It is likely that some of the pharmaceuticals are passed through the human body and out into the sewerage system. Pills that are flushed for disposal may also enter wastewater. Many drugs are only partially removed by typical sewage treatment processes.

The environmental and human health consequences of continuous low doses of chemicals in water are not known at this time but are being studied by many scientific groups.

In May, 2001, a panel of academic, government, and industry scientists determined that there is "credible evidence" that some hormone-like chemicals can affect test animals' bodily functions at very low level doses—well below the "no effect" levels that were determined by traditional testing.

A 36-member panel working for the National Institute of Environmental Health Sciences said the chemicals, called "environmental estrogens" and "endocrine disrupters," deserve greater scrutiny and additional research. Some of the chemicals, like hormones, occur naturally. Other chemicals are manufactured (synthesized) for packaging, plastics, and other products of modern life.

The panel found enough evidence of low level effects to recommend additional studies of low level doses of bisphenol A, a plastics building block used for a wide line of products, from safety helmets and impact resistant eye glass lenses to food packaging. In addition, the panel found evidence of changes in reproductive organs from low doses of estrogenic compounds, including the insecticide methoxychlor, and the fungicide vinclozolin (ScienceDaily, 2001).

Regardless of other studies reported, few toxicological studies have been done, to date, to evaluate the risks posed to humans and creatures in the natural environment, with chronic exposure to trace concentrations of various drugs.

What are endocrine disrupters? *The endocrine system is the part of the human or animal body that regulates the development, growth, reproduction, and behavior of the organism. It consists of glands that secrete hormones, and parts of cells that are deemed hormone receptors. The concern about endocrine disruption is rooted in the knowledge that certain chemicals (especially synthetic organic compounds) can mimic the hormones that serve as messengers, regulating the endocrine system that regulates our bodies.*

One of the great technological marvels of the 20th Century was the proliferation of synthetic organic chemicals, from synthetic rubber in World War II to many modern pharmaceuticals. This accomplishment, however, has been associated with many warnings about the potential for unintended outcomes. In past decades, concerns about various effects and side effects of such compounds have triggered some regulations (ending the use of DDT in the U.S.) and calls for more.

The concern remains that some of these synthetic organic chemicals may be affecting the human and natural environment in subtle and insidious ways, by interfering with the endocrine systems of humans and wildlife. A growing body of literature deals specifically with the endocrine disrupter issue.

In the human endocrine system, there are seven kinds of glands. The adrenal glands, for example, secrete some 30 different hormones that control many functions of the body. An example of how a synthetic organic chemical compound may act as an endocrine disrupter is the man-made ethinyl estradiol, which is used in birth control pills on purpose to mimic the body's natural estrogen hormone. The success of the chemical is due to the fact that it behaves in that way, flooding the body's cells to prevent real estrogen from combining with the cells' hormone receptors. The receptors link to the cells' DNA structure, to turn on or turn off certain genes, modifying cell outcomes. In the example, the cells are unable to trigger sexual reproductive processes due to the interference (disruption, or blocking action) of the synthetic chemical (Trussell, 2001).

While the whole concept is sometimes deemed a hypothesis, the reality is that the concept has been proven in wildlife. Studies have been done showing the masculinization of certain mollusks, the feminization of certain fish, and the decline of alligators in Florida, as a result of trace amounts of endocrine disrupting chemicals in the water.

Recent information (Fox et al., 2001) shows how chemical signals between alfalfa plants and soil bacteria determine nitrogen fixation in a symbiotic relationship. Some EDCs also interfere with (disrupt) this symbiotic signaling. Nitrogen fixation is a significant process that is critical to plant growth and development in the biosphere.

Investigators at Tulane University, New Orleans, La., have shown that some pesticides and planar phenolic EDCs can interfere with the exchange of signals between the plant and Rhizobium bacteria in the nitrogen-fixation symbiosis, exposing a previously unrecognized similarity to the effects of EDCs on vertebrate endocrine signaling.

David Epel, of Stanford University's Hopkins Marine Station, Pacific Grove, California, expressed to the symposium a special concern about new drugs called efflux-pump inhibitors. Designed to keep microbes from ejecting the antibiotic intended to slay them, efflux-pump inhibitors also impede the cellular pumps that nearly all animals use to get rid of toxicants. Epel worries that if pump-inhibiting drugs enter the aquatic environment, they might render wildlife vulnerable to concentrations of pollution that previously had been innocuous. (Raloff, 2000).

Sources:

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December, 1998, National Center for Environmental Health, Centers for Disease Control and Prevention, Atlanta, Georgia.

Fox, Jennifer E.; Starcevic, Marta; Kow, Kelvin Y.; Burrow, Matthew E.; and McLachlan, John A., September 13, 2001***, Nitrogen fixation: endocrine disrupters and flavonoid signalling,*** in **Nature,** Volume 413, pp. 128-129.

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Trussell, R. Rhodes, February, 2001, ***Endocrine disrupters and the water industry,*** *in* the *Journal of the American Water Works Association*, pp. 58 – 65.

Wadman, Meredith, January 18, 2001 ***Group urges survey of antibiotics in animals,*** *in* ***Nature,*** London, U.K., Volume 409, Number 6818, pp. 273.

Wilkison, Don, April 17, 2001, United States Geological Survey (USGS), Independence, Missouri, presentation to the Missouri Water Quality Coordinating Committee, Columbia, Missouri.

Combined Sewer Overflows

Problem:

Several municipalities mix sanitary sewage and stormwater runoff in combined sewer systems (CSSs). During heavy rains, the large volume of runoff overwhelms the system, and flushes untreated sewage into surface waters. The economic costs to rehabilitate systems are large. In addition, combined sewer overflows (CSOs) increase operational costs for wastewater treatment facilities (WWTF) because they treat a larger volume of waste.

Discussion:

Before clean water regulations, municipalities sometimes sent untreated sewage directly into receiving bodies of water. Thus, it was convenient to design systems that combined the sewage and the stormwater runoff (known as a combined sewer system, CSS) since they were directed to the same place. Passage of the Clean Water Act (CWA) mandated that all sanitary sewage be treated before being released into the environment, and that stopped construction of CSSs.

All of the flows in a CSS have been redirected to a wastewater treatment facility for treatment. However, when there is excessive flow caused by a rainstorm or snowmelt, it can exceed the capacity of the treatment facility and/or the CSS. Then, this excess flow is directed to surface waters without treatment, and this outfall is termed a combined sewer overflow (CSO). This overflow of untreated sanitary sewage is a pollution discharge and can violate the CWA.

Municipalities are in the process of implementing a Combined Sewer Overflow Control Plan initiated by US Environmental Protection Agency. They must characterize their CSOs (i.e. frequency, flow, pollution levels, etc.) and start using minimum technology-based controls to minimize the impact of these on the environment. Finally, they must develop a long-term control plan (LTCP) which should ensure that all their discharges comply with the Clean Water Act. There are three basic LTCP abatement

options: eliminate the overflow by separating stormwater and sanitary sewage, provide treatment of the overflow, or maintain and monitor the overflow to ensure that what comes out is sufficiently diluted as to not pollute significantly (USEPA, 2001). The latter could be a problem down the road as minimum contaminant levels are lowered, thus what was once acceptable may no longer be so.

The only CSOs that exist in northwestern Missouri are in Kansas City and St. Joseph. Kansas City has approximately 220 they know of, and are still finding ones they didn't know about. Their efforts to reduce CSO impacts have been successful. Their main effort has been focused on keeping the system free of blockages through regular inspections, and installing equipment that properly directs the flow. They are currently starting to develop a long term control plan. A big obstacle to this is finding the money for the abatement measures. For example, the city of Cape Girardeau spent $23 million and 5 years rehabilitating their CSOs (Cook, 2001), and that system was but a fraction the size of Kansas City's system. There is also the question of the outfalls that they don't know about, and it has been very difficult to locate them all. In addition, there's the added cost of treating the extra water that comes from the storm sewer system.

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Cook, Steve, May, 2001, Environmental Services Coordinator, City of Cape Girardeau. Personal communication.

United States Environmental Protection Agency/CSO homepage (USEPA), 2001: www.epa.gov/owm/cso/htm

Urban Sprawl

Problem:

Urban Sprawl adds to a number of water-related problems. These include instream sedimentation, increased flooding and drought impacts, increased watercourse pollution, increased water demand, increased spending on infrastructure, and increased human health and property damage risks.

Discussion:

The population around Kansas City has both increased and spread out into previously rural areas. The Missouri counties surrounding Jackson (Cass, Clay, Johnson, and Platte), where Kansas City is located, grew by 22 percent (70,000 people) during the 1990s (note that there has been a corresponding population increase in the surrounding Kansas counties, which adds to the problems, as water movement doesn't necessarily respect state boundaries). The population has increased in Jackson County as well, where cities such as Blue Springs increased by 25 percent. This spread of suburbia, often termed urban sprawl, leads to a host of water problems.

During construction, ground is often left bare. Heavy rains cause the soil to erode and wash into streams, causing turbidity and sedimentation. This in turn can cause problems for aquatic species (see above, "Erosion and Sedimentation"). Contractors are supposed to install sedimentation mitigation measures, such as plastic fences to keep soil on site. However, often they are not installed effectively and they are only mandated for sites over 5 acres (to be changed to 1 acre effective in spring, 2002) (Madras, 2001).

The increased impervious area (roofs and pavement) from the new development in watersheds can exacerbate stream problems related to both flooding and drought. These hard surfaces don't allow for infiltration of the water into the soil and subsequently the groundwater. Instead, this water is shed quickly to the stormwater system. Many local government subdivision regulations require that stormwater be shunted as quickly as possible into the nearest watercourse in order to prevent local flooding. Since more water is added to the system in less time, a higher flood peak with a shorter lag between rainfall and flooding occurs (figure 16). This flooding also causes greater streambank destabilization because of the increased frequency of higher peak flows.

Since many of the impervious surfaces get very hot from sunshine, the water that runs off them is heated and can increase the overall temperature of nearby streams, lakes and ponds. If this thermal pollution significantly decreases the amount of oxygen dissolved in water, it may stress fish, possibly to the point of producing a fish kill.

Some of the water shunted to the stormwater system would normally infiltrate to the groundwater, which in turn seeps back to the surface at streams (termed a stream's base flow). This is especially important during drought, as this base flow is what keeps enough water flowing in streams to sustain aquatic life. This stormwater also carries an increased pollution load into local waterways (Smith, 2001). Oil on pavement, road salts, floatables, and lawn-care chemicals are among the pollutants. An increase in pollution can render the treating of water for drinking more costly. This pollution can also kill or seriously impair the survival of aquatic biota.

There is a greater demand put on drinking water systems that were originally built to serve smaller populations. Increased demand comes

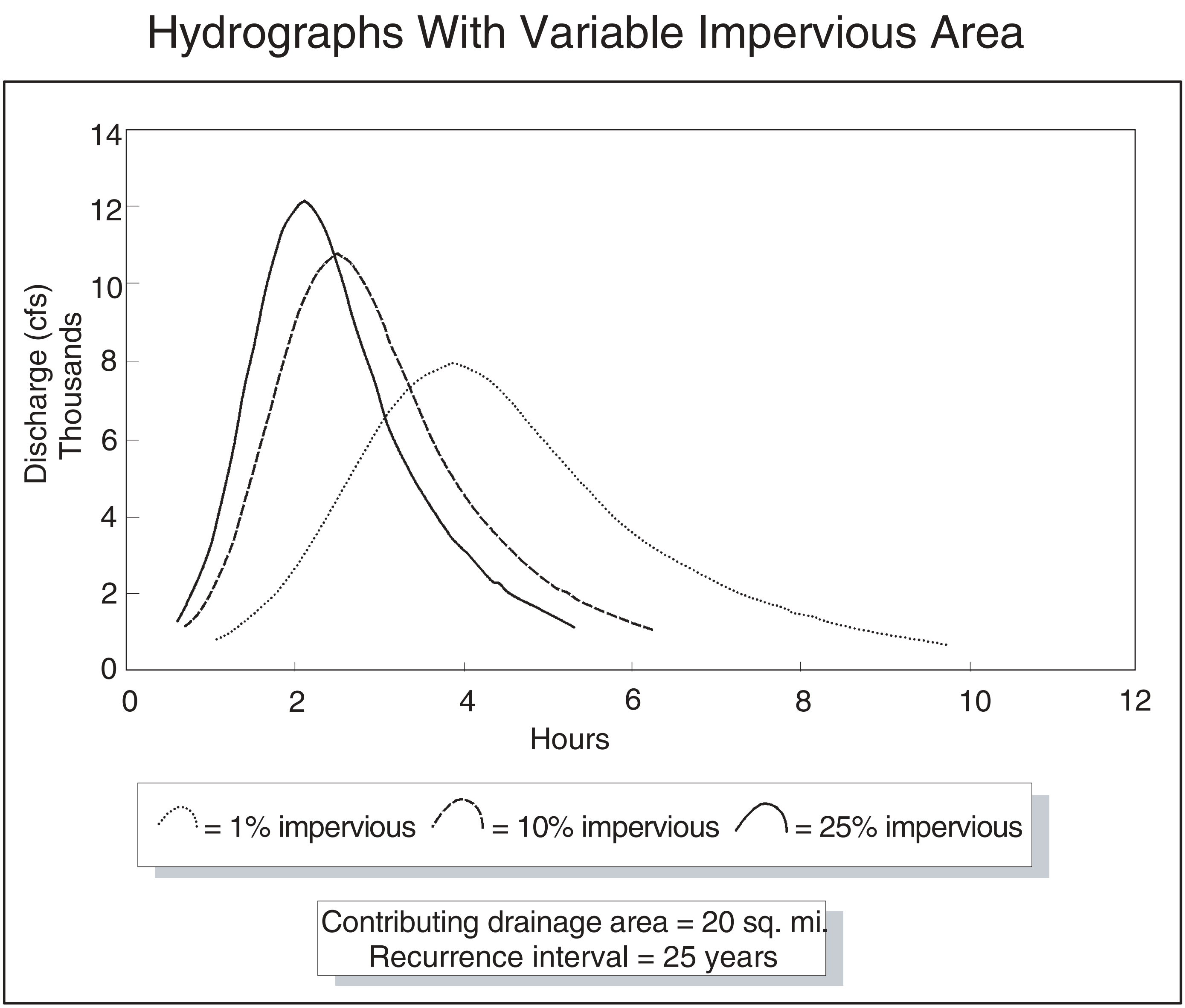

Figure 16. Hydrographs for watersheds with 1, 10, and 25 percent impervious area. Drainage area and storm magnitude are the same in the three watersheds.

both from a rise in population, but also a rise in per capita demand. This situation can stress the resource, especially in communities that are not close enough to the Missouri River to use it or its alluvium as a source of water. This increased demand can necessitate expanding treatment plants, a cost state taxes might cover. In addition, the increase in infrastructure costs might be spread throughout the entire locality, raising everybody's property taxes.

Development is currently spreading into areas that are prone to flooding along the Missouri River and associated tributaries, thereby increasing the risk of property damage and human health problems (Gaffney, 2001). Although there are levees and floodwalls to protect these areas, they can fail, with disastrous results to humans and their property.

The Federal Insurance Administration, part of the Federal Emergency Management Agency (FEMA), which implements the National Flood Insurance Program (NFIP), will accept Corps of Engineers' certification of a levee that meets a standard of protection from a once-in-a-hundred-years levee (i.e., a one percent chance flood protection levee), plus freeboard. Such certification allows the Federal Insurance Administration to make the previously flood hazard area (Zone A) behind the levee a "Zone X" (less than one percent chance of flooding). The presence of the certified levee greatly reduces the flood risk, and therefore greatly reduces the flood insurance premium on structures and contents in that zone. Property owners and renters pay the flood insurance premiums. Flood insurance, like earthquake insurance, is not a "rider" on an owner's or renter's policy, it must be purchased separately from the agent.

Unfortunately, levees can and do fail. All levees have a design limitation, such as height. Levees can be overtopped (called a design failure). Levees, like chains, are only as strong as their weakest links. Structural failures also occur during flood events, particularly in "high energy areas" of the river, such as on outside bends. In 1993, there were numerous levee failures, even the failures of certified levees, here in Missouri. Where levee failures occurred in developed areas, such as in Chesterfield Bottoms, millions of dollars in damages were realized.

The deleterious effects of urban sprawl on water resources are widespread, from pollution to flooding to ruining fish habitat. These effects are not easily categorized, and cross many disciplines. This makes addressing the issues more difficult because of their diverse nature.

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Smith, Andrew, June, 2001***, New satellite maps provide planners improved urban sprawl insight,*** www.gsfc.nasa.gov/GSFC/EARTH/Landsat/sprawl.htm

Aging Water Impoundments

Problem:

Many small reservoirs constructed utilizing funding assistance of the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) are reaching their design life and may not be able to provide all the benefits they were originally designed to provide.

Discussion:

A number of smaller reservoirs have been constructed with the assistance of the USDA

Natural Resources Conservation Service to primarily help provide flood control, prevent erosion, and sediment control pursuant to Public Law 83-566. These impoundments provide other important benefits as well. The following complete list of benefits was provided by NRCS.

- Flood control - by temporarily detaining runoff that has flowed to the dam and safely releasing it downstream through a pipe through the dam.
- Improved water quality - by settling out contaminants and sediment in the reservoir, thus protecting downstream streams and rivers.
- Water supply - by storing the water during rainy seasons for use by communities or agricultural irrigation later in the year when it is needed for crop production.
- Drinking water - by storing water in the reservoir for use by municipal and industrial entities.
- Fish and wildlife habitat - by improving wetland and vegetative habitat that creates better shelter and food sources.
- Habitat to threatened and endangered species - by creation of special features to enhance and protect threatened and endangered species.
- Wetland habitat - by creating vegetative riparian areas along the upper reaches of the reservoir.
- Restoration of riparian habitat - by providing protection of downstream channel areas that allows vegetative growth and improvement of the riparian areas.
- Recreation for local residents - by providing a source of quality fishing, hunting, picnicking, etc.
- Fire protection in rural communities - by providing a supply of water to be used for fire fighting (NRCS, 2002).

Many small reservoirs are nearing the end of their designed 50-year life span. Although, one of the purposes of these dams is to trap sediment, the years of effective sediment trapping eventually lowers the effective life of the reservoir, and decreases the flood-buffering capacity. The source of much of the sediment seems to come from construction sites and some agricultural practices which leave land open for erosion. When a stream carrying this sediment reaches an impoundment, the water slows and drops its sediment load. Over time, this silts in the reservoir, thereby diminishing water storage capacity. The siltation may also degrade fisheries by making for poor habitat, and increases turbidity, which also may negatively impact some fish. The sedimentation may also degrade recreational opportunities.

It is estimated that Missouri will need $2 million/year over the next ten years to take care of the problem (NRCS, 2001). The local sponsors (primarily local soil and water conservation districts, with a few public drinking water supply districts) will have to meet 35 percent of the cost, which could be difficult for them. The aging dams are also a problem in that their integrity is decreased from deterioration.

Dams are classified according to the risk of downstream damage in the event of a failure. Classifications basically are low, moderate, and high. When the structures were first built, there were usually agricultural land, fields and forests downstream. Today, in some situations, where a dam once was a low risk dam, there now are subdivisions downstream on land not owned or controlled by the dam owner. This may create a situation that may put people's lives at risk if the dam breaks. The Dam and Reservoir Safety Program is requiring these two dams to be upgraded to address the increased risk downstream.

In the Tabo Creek Watershed, sixty-four grade stabilization dams have been installed for erosion and sediment control. Dams in this watershed have many of the same problems of other dams across the country which are approaching their 50-year design life. These problems include deteriorating pipes and sediment filling up the reservoirs. It is estimated that it will cost $6 million to replace 44 corrugated metal pipes, and five reservoirs have problems with siltation. Unfortunately, these dams and others like them, because of their height under 35 feet, do not fall within the authority of the Dam and Reservoir Safety Program which regulates all non-federal, non-agricultural dams over 35 feet in height.

Sedimentation also degrades fisheries. It fills areas of a reservoir, making the water shal-

lower, which is poor quality habitat for the lake-adapted species. In addition, it makes the water turbid, which makes feeding difficult for sight-feeders. Pony Express Lake in DeKalb County is an example. There is decreased sedimentation as compared to 30 years ago because the Missouri Department of Conservation owns more of the watershed and manages it to reduce siltation. However, it still received a lot in its earlier years, that sediment is still there. Whenever it gets windy, this sedimentation near the surface of the lake gets stirred up easily, thereby making the lake turbid (Bonneau, 2001). Shallow-water vegetation can help hold down the sediment, however it is difficult to establish it when the water is turbid.

Sedimentation also causes problems for water managers. When exact amounts of sedimentation are unknown, the managers don't have an accurate assessment of how much water they have. This problem becomes exacerbated under drought conditions. In addition to the water quantity problem, there are water quality issues that may develop. As reservoir levels approach the bottom of the reservoir taste, odor, and turbidity problems may arise. Also, since so many communities depend on reservoirs as their drinking water source, the unchecked siltation of reservoirs could result in these reservoirs being unusable. Rehabilitating the reservoirs by dredging the silt may not be economically viable.

In Jackson County, there are four reservoirs managed by the Jackson County Parks Department. Prairie Lee Lake has large problems with stormwater runoff. It carries a lot of sediment from construction sites. In addition, there is a lot of trash washed into the reservoir during storms. Because of urbanization, the storm runoff peak flow is increased, which causes a nuisance to nearby landowners since their land is partially inundated (Staller, 2001). Part of the problem for many lakes is that there haven't been sufficient studies to quantify how long before the lake silts in. Smithville Reservoir is having siltation problems, although it appears to be happening slower than the designed 100-year life span.

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Bridge Structural Deficiencies

Problem:

The structural integrity of our bridges is decreased by the decay of aging construction and streambed scouring. If bridges fail, they pose a variety of environmental/human health, commercial transport, recreation, economic, and legal problems.

Discussion:

Missouri's bridges are decaying, which happens with all bridges as they age. Of all the bridges the Missouri Department of Transportation (MoDOT) controls, 29 percent were structurally deficient in 2000, which is the second highest percentage among the states. Although this is down from 40 percent in 1992, it still is a percentage that warrants attention (FHWA,

2001). A bridge that is structurally deficient is one that is restricted to light vehicles, requires immediate repairs to stay open or is closed. These data do not include the county roads. The director of MoDOT estimates that it would take about an extra $1 billion annually over the next two decades to finance answers to Missouri's transportation needs (including bridges) (Hungerbeeler, 2001). The longer the problems are put off, the costlier and more hazardous they become. For every dollar spent to keep a good bridge in good shape, there are ten dollars spent to rehabilitate a bad bridge (Nemmers, 2001). In addition, the delays increase the risk of bridge failure.

Scour can also cause bridge failure. This is the process whereby water removes the streambed material supporting the footing of the bridge, which causes it to collapse. Usually, this occurs when there is a large flow. With larger flows, as in flooding, water travels faster and with more turbulence, thereby increasing the streambed-erosion capability of the river. The United States Geological Survey and MoDOT are working on a multilevel assessment of bridge scour. They did an initial look at 3,300 bridges, from which they determined 225 needed further investigation (approximately 30 percent of these are in northwestern Missouri). It should be noted that their investigations have limitations (such as they are specific to a point in time), but rivers change, sometimes dramatically and quickly. Also, they cannot investigate many of the smaller roads because of unknown construction variables. This means there are numerous bridges for which no scour potential has been determined, leaving the public at risk.

Bridge failure can cause a number of problems. Bridges carry water and wastewater lines (as well as power and telecommunications lines). If a bridge were to collapse, these lines would rupture, causing inconvenience for people and possibly contaminating the river with raw sewage. Since it takes a long time to replace a bridge, these services could also be disrupted for an extended period of time. A downed bridge in a river can impede the flow of commercial and recreational navigation, which causes economic losses and inconveniences for people, impacting all the river ports upstream and at St. Louis or other endpoint ports. The port of Waverly has part of its terminals under the bridge, which could be destroyed by a bridge collapse (Hays, 2001). This would further impede commercial navigation on the river. Without a bridge, a river becomes an obstacle to the flow of traffic and goods across the river.

Sources:

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Hungerbeeler, Henry, February 20, 2001, quoted in ***State bridges in trouble***, Columbia Daily Tribune.

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Competing Uses of the Missouri River

Problem:

The Missouri River is a major feature of the economic, environmental and social landscape of northwestern Missouri. The sheer size and complexity of the river makes it a very difficult resource to manage and presents special challenges to our state.

Discussion:

The Missouri River is large, in terms of the land area it drains, the volume of water that it carries, the uses to which its water is put, and the day-to-day economic, recreational and so-

cial effects it has on the lives of literally millions of Missourians. However, its flow and capabilities for use are finite, and these limitations at times may lead to conflicts among users.

The headwaters of the Missouri River is in the Rocky Mountains of Wyoming and Montana. Its middle reaches (from eastern Montana, through the Dakotas, and northern parts of Nebraska) are contained in a series of six main stem reservoirs (Fort Peck Dam and Lake, Garrison Dam and Lake Sakakawea, Oahe Dam and Lake, Big Bend Dam and Lake Sharpe, Fort Randall Dam and Lake Francis Case, and Gavins Point Dam and Lewis & Clark Lake). The reach of the river below Gavins Point Dam (the lowest dam on the main stem of the river) is constrained by levees and has a navigation channel, which the Corps of Engineers maintains (figure 17).

The management of the Missouri River goes far beyond the borders of the state. The U.S. Army Corps of Engineers has been given the responsibility to manage the Missouri River reservoir releases. To accomplish this task the Corps of Engineers has developed a Missouri River Master Water Control Manual (Master Manual) directing how they are to operate the main stem dams of the river. To help with this task the Corps has asked for input from interested parties. This input has come from numerous state and federal agencies, special interest groups, individual citizens, Indian tribes and the Canadian government.

The management of the river must address its many uses. The principal economic-social uses of the Missouri River are drinking water supply, industrial-commercial water supply, agricultural (irrigation) water supply, hydroelectric

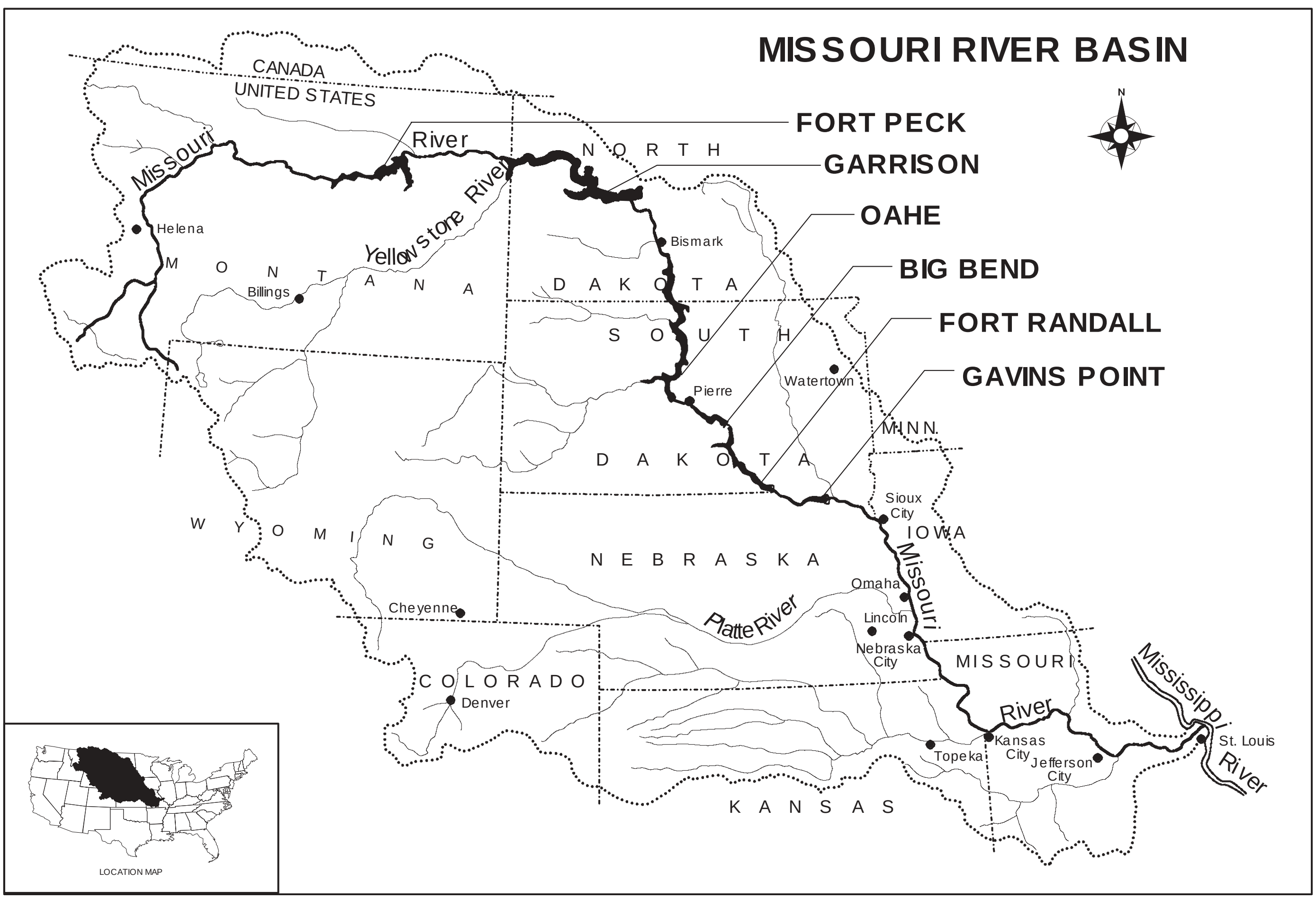

Figure 17. Missouri River Basin. Names in heavy black type are the main-stem dams that the Corps of engineers use to control the flow of the Missouri River.

power production, cooling for thermoelectric power generation, navigation; and environmental-social-economic uses include recreation, and fish and wildlife. Other considerations include water quality, river alluvium and adjacent area groundwater recharge, sediment and flood control, and environmental benefits (USACE, 1994).

Due to the complexity of each of these uses and how they affect each other further detail concerning them is beyond the scope of this publication. Detailed information can be obtained from a variety of websites and other sources.

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Streams Flowing into Missouri from Other States

Problem:

Watercourses flow into Missouri from Iowa, a riparian water law state, and from Kansas, a prior appropriation water law state. Missouri does not have agreements with these other states to assure streamflow. This, along with a lack of surface water impoundments and poor overall groundwater quality/quantity, presents a challenge to those living in this area.

Discussion:

The four counties on the Iowa state line in northwestern Missouri receive water from Iowa by way of several rivers and creeks, some of which have dams built on them or on their tributaries in Iowa (figure 18). Streamflow typically is from north to south in this area.

The northwestern corner of Missouri, where the rivers mentioned above enter the state, generally receives the least amount of rainfall in the state, averaging 35 inches or less, per year, over the long term (Vandike, 1995). Accordingly, this is an area where drought can take a serious toll.

In addition, because shallow wells can use only the limited supplies found in glacial till aquifers, and deep wells have water that is not potable, cities and other major water users typically must develop surface water reservoirs for large supplies.

The Corps had proposed to build a series of dams in northwestern Missouri, which have not been built to date. These would have insured adequate water supply in the case of drought. Smithville Dam was the only one of the group of proposed dams ever constructed. The fact is that northwestern Missouri remains very vulnerable to drought, and Missouri has no guarantee that the rivers will keep flowing out of Iowa.

Other, smaller reservoirs have been built over the years. Mozingo Lake is one example. It is the largest impoundment built in Missouri by the Natural Resources Conservation Service, USDA, and the local Soil and Water Conservation District.

As it is, many residents and businesses of this part of Missouri are dependent on shallow glacial till aquifers or meager surface water supplies for all purposes. This fact limits economic development opportunities, such as value added processing of rural products, like meat processing and meatpacking, and grain crop processing, such as ethanol production. “Lack of groundwater and insufficient surface water in west and north Missouri has been a major factor in out-migration of population due to a lack of industry development opportunities” (McIntosh, 2001.)

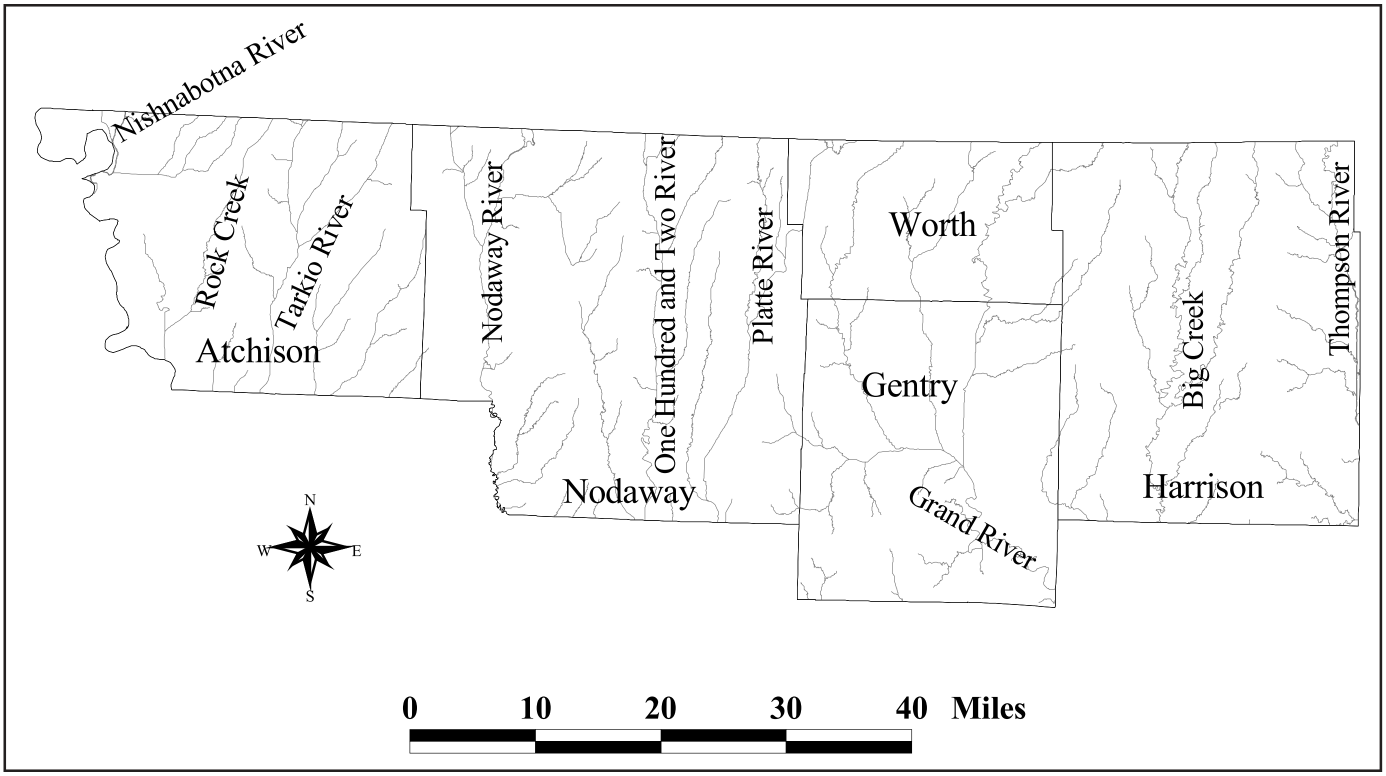

Figure 18. Streams flowing from Iowa to Missouri.

Without some sort of agreement between the State of Missouri and the State of Iowa relative to the continuing flow of water into Missouri during any future drought, the meager sources of water that exist today in the region could disappear at some future time. Several of those streams that cross into Missouri from Iowa have river gauges on them, and many of those gauges recorded no flow (0 cfs) during the “Dust Bowl” years.

Such an occurrence would have human and environmental impacts. There is no large reservoir of potable water north of Smithville Reservoir. There is little regionalization of water supply systems in this region, and if a water supply were to dry up, there would be no alternate source of water for human consumption. Wildlife also is dependent on water to live. In a severe drought, wild creatures suffer and die. There is no reserved minimum flow for aquatic life.

Streams from Kansas

In the southern part of the region, the flow of streams is from west to east. The Kansas River is the largest river flowing east out of Kansas, entering the Missouri River at Kansas City. Numerous tributaries of the Kansas River are dammed for flood control and other purposes. Examples are Milford Lake, near Junction City; Tuttle Creek Lake, near Manhattan; Perry Lake, east of Topeka; and Clinton Lake, near Lawrence.

Kansas is a prior appropriation water law state. This means that the state considers that it owns the water on behalf of the people of Kansas, and may use all of the water that is within the boundaries of the state. The Kansas Water Office allocates water to those residents who claim it.

Another major stream that flows out of Kansas into Missouri is the Marais des Cygnes

River, which is dammed above Melvern, Kansas, to form Melvern Lake. It flows out of Linn County, Kansas, into Bates County, Mo. This is the principal tributary of the Osage River in Missouri (Vandike, 1995).

A major tributary of the Marais des Cygnes River is dammed above Pomona, Kansas, to form Pomona Lake. So, two major reservoirs, and two smaller reservoirs, retain water of this river in Kansas. Kansas claims to own all the water west of the state boundary. In time of drought, the state is not duty bound by its water law to release water into Missouri.

Bates County, Missouri, is at least partly dependent on water from the Marais des Cygnes River, which flows out of Kansas. Butler, the seat of Bates County, uses water intakes in the Marais des Cygnes River and its tributary, Miami Creek, as well as a 67-acre reservoir in the Miami Creek watershed (Vandike, 1995). If the Marais des Cygnes River went dry, the City of Butler would not have adequate water supply.

The Marais des Cygnes Waterfowl Refuge is situated in Linn County, Kansas (just west of the state line), so it is likely that Kansas will try to keep some water flowing into that area, even in the event of a major drought. Without some sort of agreement between the State of Missouri and the State of Kansas relative to the continuing flow of water into Missouri during any future drought, the possibility exists of that river running dry before it crosses the state line. The human and environmental consequences of that happening would be disastrous.

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Biological Contamination of Water

Problem:

Surface waters and groundwaters of Missouri could be contaminated by various disease vectors and other pollutants, including antibiotic resistant bacteria and viruses, from on-site sewage disposal and stormwater runoff.

Discussion:

The principal reason for sewage treatment is to remove or destroy illness-causing pathogens from wastewater, so as to prevent disease among human beings. Unfortunately, some sewage treatment methods do not completely accomplish this purpose under all circumstances. Also, stormwater runoff is not treated to remove pathogens.

In northwestern Missouri, much of the territory is rural, and many of the residents rely on septic tanks and leach fields for on-site sewage treatment. There also are livestock operations that rely on sewage lagoon systems for on-site waste treatment. The issue is that many of these on-site systems have inherent problems and high failure rates. Stormwater running off from pastures and feedlots has no treatment at all.

In a report entitled, "Virus Transport from *Septic Tanks to Coastal Waters, in* ***Small Flows Quarterly,*** Summer, 2000, we are told that failing or malfunctioning septic systems are the

most frequently reported source of groundwater contamination in the U.S.

There are numerous issues related to septic tanks and leach fields that can cause failure or malfunction in septic systems. The primary issue is siting. The location of any on-site sewage treatment system is important, but septic tanks and leach fields require certain kinds of soils for them to function properly.

In northwestern Missouri, many of the soils have severe limitations for proper functioning of septic systems. Leach fields, also called absorption fields, are areas in which effluent from a septic tank is distributed into the soil through subsurface tiles or perforated pipe.

County soil survey reports show, in more detail, soils and limitations for specific parcels of land. Soil survey reports are available from county USDA Service Centers, or by calling the Natural Resources Conservation Service state office in Columbia, Missouri. For actual siting of septic systems, it is necessary to examine soil characteristics in the field.

In addition, a soil percolation test determines the rate at which water will soak into a hole in the ground. Local and State Health Departments require soil percolation tests prior to permitting any prospective on-site sewage disposal system on house lots under three acres in size. This is mandated by state law, (Sections 701.025 – 701.039, RSMo) in order to protect the public health. For more information see Gaffney and Hays, 2000, p. 99.

The highest percentage of soils suitable for on-site sewage disposal are located in the loess hills area where steep slopes complicate the siting process. All-in-all, about 86 percent of the soils in the northwestern region of Missouri have severe limitations for septic tank absorption fields. The main limitations for septic tank leach fields in the northwestern Missouri region are high water tables, low permeability, flooding, and slope (Young, 2001).

Microbes can pass through septic systems that are not properly functioning. For example, according to the ***Small Flows Quarterly*** article, micro-organisms that are a high risk to water quality and public health include enteroviruses, coxsackieviruses, hepatitis A viruses, the Norwalk virus associated with diarrhea, aseptic meningitis, and myocarditis viruses. Their small size (nanometer range) and structure (a protein coat surrounding a core of nucleic acid) enhances their transport and survival (Rose, et al., 2000).

Stormwater, particularly the "first flush" of runoff from either farm fields or paved urban areas, contains fecal coliform bacteria, and fecal streptococcus bacteria. Quantities vary with the sources. The bacteria come primarily from domestic animal wastes. In a study done in Independence, Missouri, during 1991-1993, the U.S. Geological Survey found tens of thousands of colonies of these bacteria in samples of stormwater from residential, commercial, and industrial watersheds (Schalk, 1994).

Whether from stormwater or from fertilized, irrigated fields, contaminated water flowing overland can enter wells that are not properly cased and grouted, thereby polluting groundwater. A number of pathogens, especially viruses, can live months in groundwater.

Because livestock are routinely given nontherapeutic doses of antibiotics to promote growth and good health, many people have charged that pathogenic microbes are becoming antibiotic resistant. Such resistant disease-causing "germs" are frustrating physicians and hospital administrators as they attempt to combat human diseases (Wadman, 2001).

In some streams in northwestern Missouri, effluent (treated discharges) from wastewater treatment plants constitute most or all of the flow in the streams during dry months, especially during periods of drought. The effect of this condition on bottom dwelling organisms can be detrimental.

One innovation over the past decade has been the use of constructed wetlands for "final finishing" of treated wastewater. This refers to the use of wetland plants to take up nutrients and contaminants, and to trap microbes, where they can do no more harm. More study of the various alternative treatment methods is ongoing.

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Does Water Play a Role in Vectoring of TSE?

Problem:

A series of transmissible spongiform encephalopathies (TSE) are appearing in various mammal species. Some are clearly transferable to humans, others may not be. These diseases can affect both livestock and wildlife. Does water play a role in its spread?

Discussion:

Unlike most other communicable diseases, the suspected infectious agent in TSEs, prion protein or prion (rhymes with “Leon”) is not alive (as opposed to a virus or bacteria, which are alive). Prions normally exist within all brains. Various forms of mutant prions can exist in live animals' brains by developing spontaneously or by being introduced by eating something that contains the prions. The disease grows within the body by mutant prions converting the structure of the regular prions into that of the mutant form. TSE causes the brain to develop holes hence, “sponge-form”, which always causes death.

In the 1980s and 1990s, the cattle TSE (mad cow disease, also known as bovine spongiform

encephalopathy, or BSE) was widespread in the United Kingdom. It is believed that BSE was concentrated in the U.K. cattle population by their being fed protein supplements made with rendered body parts of ruminants (primarily cattle and sheep) that are suspected to have had the disease. When humans consume this infected beef, they can develop a human form of TSE, variant Creutzfeldt-Jakob Disease (vCJD). The diseases' incubation time in cattle is 30 months; in humans, it could be 15-20 years or more. Another form of TSE, chronic wasting disease (CWD), occurs in deer and elk. Colorado recently completed a field test in which they validated the first test available for detecting CWD in live animals. Previous research has shown that aberrant prion protein accumulates in deer tonsils beginning in early stages of the disease, making tonsillar biopsy a potential detection tool (Colorado Division of Wildlife, 2002). This test is reportedly not effective on elk. Northwestern Missouri has plenty of deer, cattle, and other species which are susceptible to various forms of the diseases, including the humans who eat these animals.

It has been shown that CWD is highly contagious among elk. An uninfected herd of elk was moved to an area where there had previously (two years earlier) been infected elk, and the new herd developed CWD (Kleiboeker, 2001). They believe the transfer was from grazing in the same place, although the exact mechanisms for transfer are not understood. The Missouri Departments of Conservation and Agriculture are continuing to step up efforts to protect the state from the threat of CWD. The agencies recently signed a formal agreement to focus on identifying and implementing steps to reduce the risk of CWD entering Missouri (Ramsey, 2002).

There are currently many uncertainties about the disease. Exactly how it destroys the brain is not known. The Missouri Department of Conservation states "evidence suggests infected deer or elk may transmit the disease through animal to animal contact or by contaminating feed or water sources with saliva, urine or feces (Ramsey, 2002)." It appears that the mutant prion is not soluble in water, but little is known about how it might be transported in the environment. Could it be moved attached to sediment or other substances in a stream? Could it move up the aquatic food chain? Unlike many other proteins, the mutant prions are very difficult to destroy, persisting unchanged for over two years in soil (Brown, 2001). This persistence increases the opportunities that it could move within the environment. Also, water acts as a gathering point for both livestock and wildlife to drink, thereby creating an opportunity for concentrating the prions that might come from saliva, urine, or feces.

Sources:

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Regional Water Use Opportunities and Observations

This report documents water use problems that have been identified in northwestern Missouri. In the process of creating this report, several "success stories" and opportunities in water use have been recognized as well. Although the goal of this series is to identify problems rather than offer solutions, some of these findings are described below. By taking note of successes (and opportunities for success), we recognize approaches that work, and can use them as stepping stones to problem resolution. Water use opportunities are presented in this section to stimulate further thought and discussion, without endorsement of feasibility or merit.

Lewis and Clark Celebration

The bicentennial celebration of the Lewis and Clark Journey of Discovery is coming in the years 2004-2006. Many tourists will be coming to the area, with the Missouri River as the focus of activities. This is an opportunity for river communities to open their doors to tourists, bringing in dollars to the local economies, as well as create possibilities for expanded recreation on the river in the future. However, they must be prepared with the infrastructure to effectively welcome them. This is also an excellent opportunity to educate the public about the social, economic and environmental aspects of the "Big Muddy."

Alternative Water Source Funding

The Environmental Protection Agency (EPA) is starting pilot project funding for alternative water sources beginning in 2002. These monies are for projects "...designed to provide municipal, industrial, and agricultural water supplies in an environmentally sustainable manner by conserving, managing, reclaiming, or reusing water or wastewater..." (Steiert, 2001). This is pertinent in the northwestern part of Missouri, an area particularly susceptible to drought. Many of the rural areas do not have a large financial base from which to draw. These funds could help strengthen water systems, which in turn could stimulate economic growth by assuring commercial and industrial enterprises an adequate source of water.

Source:

Steiert, Robert, USEPA, Region VII. Personal Communication, July, 2001.

Drinking Water Source Protection

Rural areas of northwestern Missouri usually depend on surface sources for their drink-

ing water, often from reservoirs. This source of water may be contaminated due to various land use practices. There is a new program, MOCREP (Missouri Conservation Reserve Enhancement Program), designed to help reduce the number of contaminants entering public water supply reservoirs. Under contractual agreements, the program pays farmers to put land into the program for 15 years. These lands, which convert cropland and/or pastureland to native grasses, trees, wildlife plantings, cool season grasses, etc., act to filter chemicals entering the water, thereby helping to decrease contamination of water supply reservoirs. This funding could help local communities augment the quality of their source of drinking water.

MoCREP is Missouri's program that is tailored after the national CREP (Conservation Reserve Enhancement Program) program and uses state and federal resources to help solve conservation problems. The program combines an existing USDA program, the Conservation Reserve Program (CRP), with state programs to meet specific state and national environmental objectives.

Sources:

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Security Assistance

After the September 11, 2001, terrorist attacks, security of water supplies and other water-related infrastructure (dams, source water, treatment plants, commercial navigation) has been a concern. As this is a new issue in terms of it being a larger problem, there currently is no agency coordinating this protection. The new federal Office of Homeland Security (OHS) has a mission to help protect U.S. citizens, which includes protecting water-related infrastructure, supply and quality. The OHS has the potential to help coordinate this process, with the help of local, state and federal agencies.

Planned Development Can Prevent a Variety of Water Problems

Although there are several regulations designed to prevent water problems (e.g. stormwater abatement during construction, storm sewer design standards, etc.), a coordinated approach incorporating water into the planning process is not widespread or used within the region. This is despite ample literature on the subject (such as Planning and Land and Water magazines) and the availability of technical assistance within the industry. A study in Minnesota indicated "...unplanned and poorly managed development results in significant environmental and fiscal costs..." (EQB, 1998). This conclusion is probably applicable in Missouri as well. Code enforcement is not the issue. The issue is thoughtful, educated planning of new developments. One way this could be enhanced is by true-costing water and water problems: If a developer or community were held monetarily liable for the impacts related to their development (instead of, for example, passing it to someone downstream), they would do a lot more from the beginning of the project to prevent these problems (prevention is usually cheaper than mitigation).

For example, a housing development of over 100 homes in Davis, California, was one of the few places in town not to have flooding in the winter of 1995, due to the developers' foresight to incorporate swales into the layout of the subdivision (Frueh, 2001). These swales also enable better groundwater recharge, and their lawn irrigation is decreased as compared to other sites in town. Although this cost the developer a bit more up front to design and build the subdivision this way, the houses sold for more money and continue to sell for approximately 10% more than comparable houses elsewhere in the city.

Sources:

Environmental Quality Board (EQB), 1998, ***Soundings: a Minnesota water plan assessment,*** St. Paul, Minnesota, 29 p.

Frueh, Terry, Hydrologist, Missouri Department of Natural Resources, Geological Survey and Resource Assessment Division, Water Resources Program. Personal communication, 2001.

Possible Increased Base Flow in the Thompson River

Based on USGS Water Supply data and work done with a USGS computer program "HYSEP," which performs hydrograph separation, estimating the groundwater or base flow component of stream flow, it appears that during the past sixty years, base flows of the Thompson River (Harrison, Grundy, and Livingston

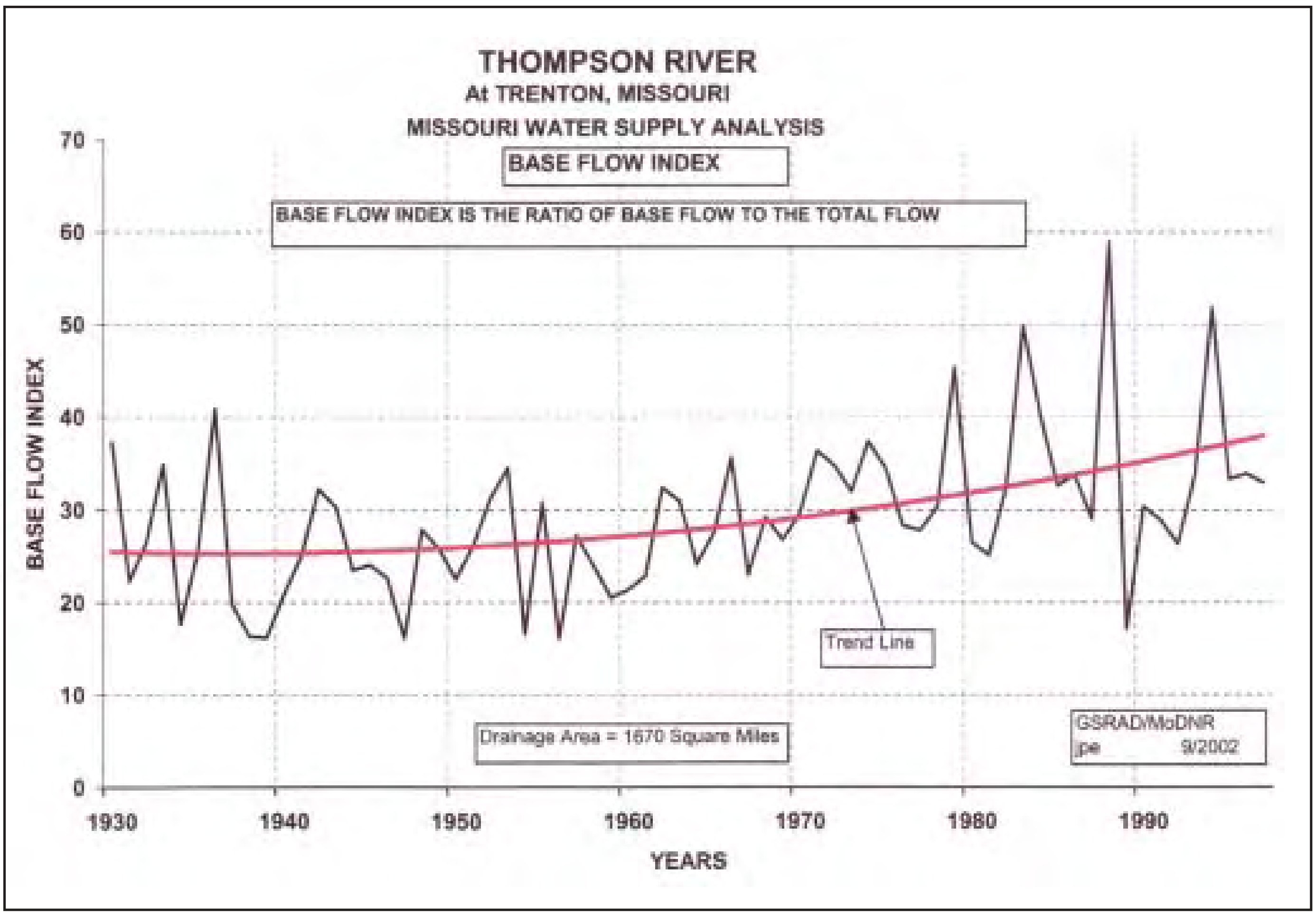

Figure 19. This graph is based on Thompson River USGS gage data at Trenton, Missouri, gage number 06899500, at this location from August, 1928, through the present. The channel of the river was straightened by dredging early in the 20th Century, prior to the period of record. Senior Hydrologist Jerry Edwards (USDA, Retired), used a USGS computer program to separate base flow from total flow to determine the base flow as a percentage of the total flow in the Thompson River. The "sawtooth" line on the graph shows those data for the time period covered by the gage. Only the 1993 data were omitted from the analysis, due to the exceptional flooding conditions of that year. This graph was produced in September, 2002.

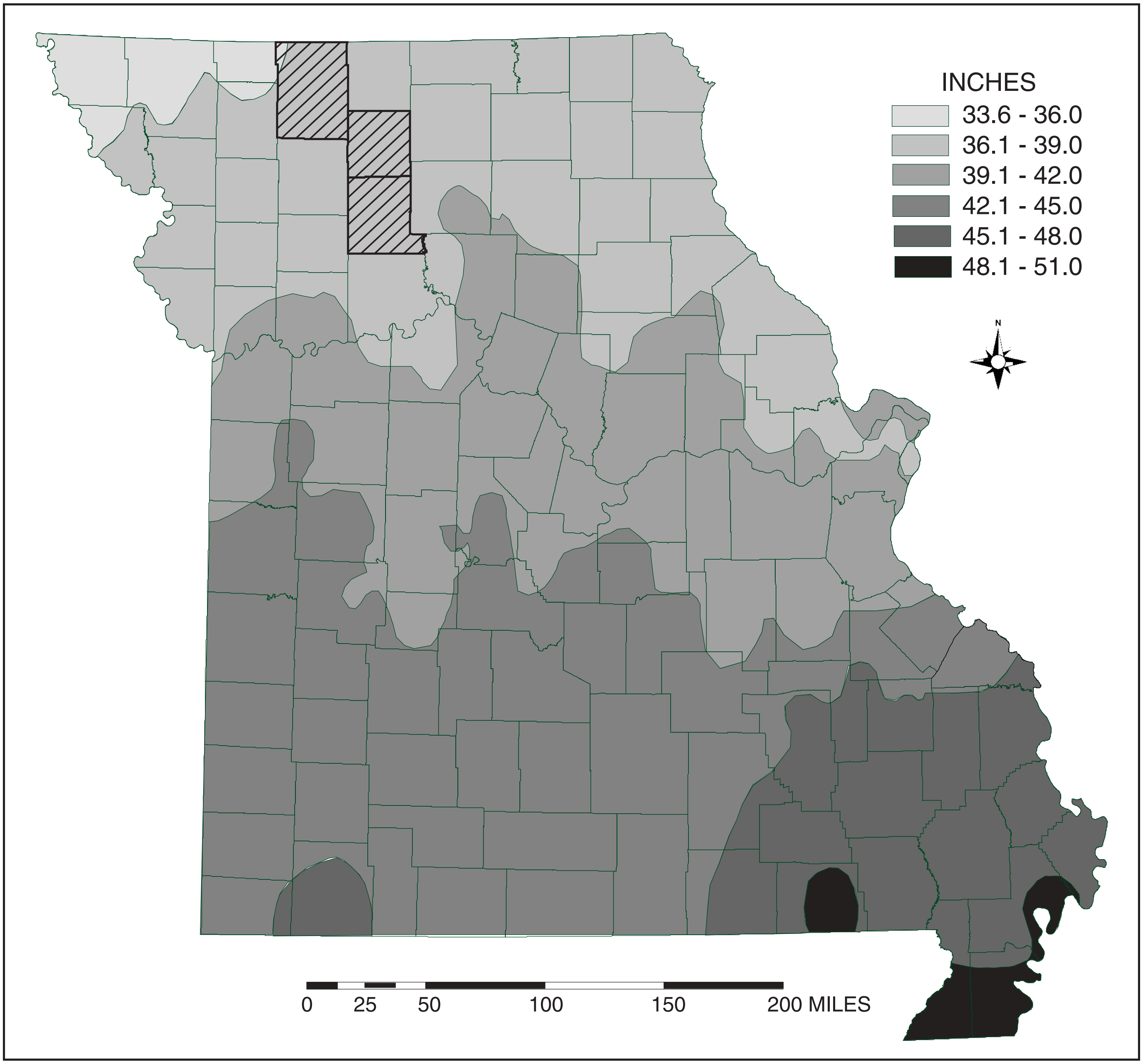

Figure 20. Missouri annual precipitation, 2002. This is based on late 20th Century data from more than 100 stations covering the period from 1971-2000 (30 years). Source: Office of State Climatologist, University of Missouri - Columbia.

counties) have been on a long-term rising trend (figure 20). Precipitation also has been rising in this part of Northwestern Missouri during this same time period (figure 21). Compare to figure 22 which shows rainfall averages up to 1967.

No attempt has been made to estimate the cause and effect of changes in base flow. Base flow estimates will be different for each stream because of changes in rainfall, upstream reservoirs, soil types and infiltration, vegetation, topography, and land treatment practices including tillage.

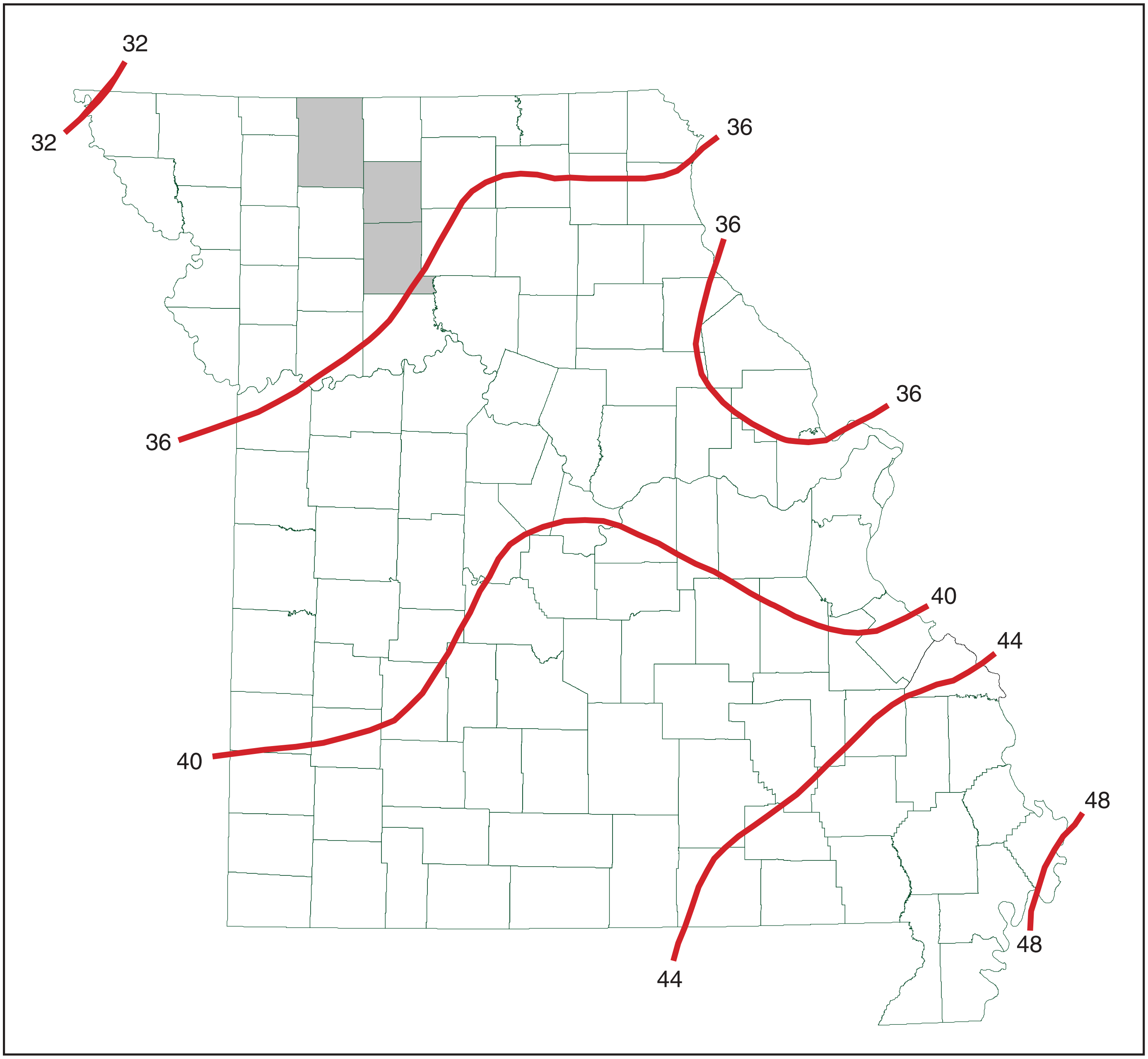

Figure 21. Missouri annual precipitation, based on data pre 1967. This is for comparison to present data shown in Figure 20.

Sources:

Edwards, Jerry, September 4, 2002, Missouri Department of Natural Resources (consulting hydrologist), personal communication.

Hu, Steve, 2002 draft report, Missouri Department of Natural Resources (consulting climatologist).

Missouri Department of Natural Resources, Division of Geology and Land Survey, 1986, ***Missouri water atlas,*** 100 pp.

USGS, ***Missouri Water Year 2002,*** annual report of stream gage data.

Comments Received

Topics in Water Use: Northwest Missouri was reviewed at several stages of preparation. Ultimately, the draft report was placed on the Department of Natural Resources' Geological Survey and Resource Assessment Division's Internet web page for access and comment by the public. This request for comments was publicized statewide by the issuing of a newsrelease advertising this action. The department sought public comment for 30 days on this report. Although the report was accessed by many people, no public comments were received.

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